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NATIONAL TECHNOLOGY INNOVATION ACT
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# HEARINGS

BEFORE THE

## SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

## COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

NINETY-SIXTH CONGRESS

FIRST SESSION

ON

## S. 1250

TO PROMOTE UNITED STATES TECHNOLOGICAL INNOVATION FOR THE ACHIEVEMENT OF NATIONAL ECONOMIC, ENVIRONMENTAL, AND SOCIAL GOALS, AND FOR OTHER PURPOSES

---

JUNE 21, 27, AND NOVEMBER 21, 1979

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Serial No. 96–63

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Committee on Commerce, Science, and Transportation

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# NATIONAL TECHNOLOGY INNOVATION ACT

THURSDAY, JUNE 21, 1979

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
*Washington, D.C.*

The subcommittee met at 9:30 a.m., in room 6226 of the Dirksen Senate Office Building, Hon. Adlai E. Stevenson (chairman of the subcommittee) presiding.

## OPENING STATEMENT BY SENATOR STEVENSON

Senator STEVENSON. The subcommittee will come to order.

Today we begin hearings on S. 1250, the National Technology Innovation Act. Two years ago, we began reviewing the condition of American industrial technology. One of our distinguished witnesses this morning told me that this review was the first of its kind in the country's history, and then he qualified himself, as he recalled efforts by Herbert Hoover when he was Secretary of Commerce. He modestly overlooked his own efforts in the 1960's. I refer to Mr. Hollomon.

Our review continues this morning. This bill is part of a broad effort to review the condition of industrial innovation in the United States. It is not intended to be a comprehensive remedy to what we sense to be a declining capacity or relevant capacity for industrial innovation in the United States. It is a tentative first step.

The National Technology Innovation Act will improve the ability of universities and industry to collaborate in Centers for Industrial Technology in generating new technological ideas for the marketplace. It will also improve the government's ability, through an Office of Industrial Technology, to understand the technical and economic conditions that determine productivity, employment, and trade performance in specific sectors.

It's probable that additional legislation will be needed if the United States is to compete in a new, highly competitive marketplace. The additional efforts fall into such subject areas as trade, patents, regulatory, Federal procurement, antitrust policies.

The subcommittee will conduct hearings on July 23 and 27 on S. 1215, the Science and Technology Research and Development Utilization Policy Act, introduced by Senator Schmitt, cosponsored by Senator Cannon and myself.

The White House has initiated a domestic policy review of industrial innovation. The Secretary of Commerce is responsible for this. Interagency review and recommendations to the President will be made shortly.

While we are interested in what the administration will recommend, we cannot depend on this review alone. Hearings on the administration's proposals will be scheduled as soon as they are available, and our review will continue.

[The bill follows:]

96TH CONGRESS
1ST SESSION

# S. 1250

To promote United States technological innovation for the achievement of national economic, environmental, and social goals, and for other purposes.

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IN THE SENATE OF THE UNITED STATES

MAY 24 (legislative day, MAY 21), 1979

Mr. STEVENSON (for himself, Mr. CANNON, Mr. HOLLINGS, Mr. INOUYE, Mr. FORD, Mr. RIEGLE, Mr. MOYNIHAN, and Mr. SCHMITT) introduced the following bill; which was read twice and referred to the Committee on Commerce, Science, and Transportation

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# A BILL

To promote United States technological innovation for the achievement of national economic, environmental, and social goals, and for other purposes.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That this Act may be cited as the "National Technology Innovation Act of 1979".

**SEC. 2. FINDINGS.**

The Congress finds and declares that:

(1) Technology and industrial innovation are central to the economic, environmental, and social well-being of citizens of the United States.

(2) Technology and industrial innovation offer an improved standard of living, increased public and private sector productivity, creation of new industries and employment opportunities, improved public services and enhanced competitiveness of United States products in world markets.

(3) Many new discoveries and advances in science occur in universities and Government laboratories, while the application of this new knowledge to commercial and useful public purposes depends largely upon actions by business and labor.

(4) Industrial innovation in the United States may be lagging when compared to historical patterns and other industrialized nations.

(5) Increased industrial innovation would reduce trade deficits, stabilize the dollar, increase productivity gains, increase employment and stabilize prices.

(6) Government antitrust, economic, trade, patent, procurement, regulatory, research and development, and tax policies have significant impacts upon industrial innovation and development of technology, but there is insufficient knowledge of their effects in particular sectors of the economy.

(7) No national policy exists to enhance technological innovation for commercial and public purposes.

SEC. 3. PURPOSE.

It is the purpose of the Congress in this Act to enhance technological innovation for the improvement of the economic, environmental and social well-being of the United States.

SEC. 4. DEFINITIONS.

As used in this Act, unless the context otherwise requires, the term—

(1) "Office" means the Office of Industrial Technology established under section 5 of this Act.

(2) "Secretary" means the Secretary of Commerce.

(3) "Director" means the Director of the Office of Industrial Technology, appointed pursuant to section 5 of this Act.

(4) "Centers" means the Centers for Industrial Technology established under section 6 of this Act.

(5) "Nonprofit institution" means an organization owned and operated exclusively for scientific or educational purposes, no part of the net earnings of which inures to the benefit of any private shareholder or individual.

(6) "Panel" means the Industrial Technology Review Panel established pursuant to section 9.

**SEC. 5. COMMERCE AND TECHNOLOGY INNOVATION.**

(a) IN GENERAL.—The Secretary shall establish and maintain an Office of Industrial Technology in accordance with the provisions, findings, and purposes of this Act.

(b) DIRECTOR.—The President shall appoint, by and with the advice and consent of the Senate, a Director of the Office, who shall be compensated at the rate provided for level V of the Executive Schedule in section 5316 of title V, United States Code.

(c) DUTIES.—In addition to any other duty prescribed by law or assigned by the Secretary, the Director, on a continuing basis, shall—

(1) determine the relationships of technological developments and international technology transfers to the output, employment, productivity, and world trade performance of United States and foreign industrial sectors;

(2) determine the influence of economic, labor and other conditions, industrial structure and management, and government policies on technological developments in particular industrial sectors worldwide;

(3) identify technological needs, problems, and opportunities within and across industrial sectors that if addressed could make a significant contribution to the economy of the United States;

(4) assess whether the capital, technical and other resources being allocated to domestic industrial sectors which are likely to generate new technologies are adequate to meet private and social demands for goods and services and to promote productivity and economic growth;

(5) propose and support studies and policy experiments, in cooperation with other Federal agencies, to determine the effectiveness of measures with the potential of advancing United States technological innovation;

(6) recommend through the Secretary to the President and Congress government measures with the potential of advancing United States technological innovation and exploiting innovations of foreign origin; and

(7) assist in the preparation of the report required under section (d) and publish the results of studies and policy experiments.

(d) REPORT.—The Secretary shall prepare and submit to the President and Congress, within 3 years after the date of enactment of this Act, a report on the progress, findings, and conclusions of activities conducted pursuant to sections 5 and 6 of this Act and recommendations for possible modifications thereof.

SEC. 6. CENTERS FOR INDUSTRIAL TECHNOLOGY

(a) ESTABLISHMENT.—The Director shall provide assistance for the establishment of Centers for Industrial Technology. Such Centers shall be affiliated with any university, nonprofit institution, or group thereof that applies for and is awarded a grant or enters into a cooperative agreement under this section. The objective of the Centers is to enhance technological innovation through—

(1) the participation of individuals from industry and universities in cooperative technology innovation activities;

(2) the development of the generic research base important for technological advance and innovative activity in which individual firms have little incentive to invest, but which may have significant economic importance, such as manufacturing technology;

(3) the conduct of research that contributes to the scientific basis of health, safety, and environmental regulations for the purposes of improving regulatory actions and minimizing costs of duplicative research;

(4) the education and training of individuals in technology innovation;

(5) the improvement of mechanisms in the dissemination of scientific, engineering, and technical information from universities to industry;

(6) the utilization of the capability and expertise, where appropriate, that exists in Federal laboratories; and

(7) the development of continuing financial support from industry and universities through, among other means, fees, licenses, and royalties.

(b) ACTIVITIES.—The activities of the Centers shall include, but need not be limited to—

(1) research supportive of technology and industrial innovation including cooperative industry-university basic and applied research;

(2) assistance in the evaluation and development of technological ideas supportive of industrial innovation and new business ventures;

(3) technological assistance and advisory services to industry; and

(4) curriculum development and instruction in invention, entrepreneurship, and industrial innovation.

Each Center need not undertake all of the activities under this subsection.

(c) REQUIREMENTS.—Prior to establishing a Center, the Director shall find that—

(1) consideration has been given to the potential contribution to productivity, employment, and economic

competiveness of the United States of the activities proposed under the Center;

(2) a high likelihood exists of continuing participation, advice, financial support, and other contributions from the private sector;

(3) the host university or nonprofit institution has a plan for the management and evaluation of the activities proposed within the particular Center, including consideration of means to place the Center, to the maximum extent feasible, on a self-sustaining basis; and

(4) suitable consideration has been given to the university's or nonprofit institution's capabilities and geographical location.

(d) PLANNING GRANTS.—The Director is authorized to make available nonrenewable planning grants to universities or nonprofit institutions for the purpose of developing a plan required under subsection (c)(3).

(e) RESEARCH AND DEVELOPMENT UTILIZATION.—To promote technology innovation and commercialization of research and development efforts, each Center has the option of acquiring title to any invention conceived or made under the auspices of the Center that was supported at least in part by Federal funds: *Provided,* That—

(1) said option shall be exercised at the time of disclosure of invention or within such time thereafter as may be provided in the grant or cooperative agreement;

(2) the Center intends to promote the commercialization of the invention and file a United States patent application;

(3) licensing be on a nonexclusive basis except where commercialization or industrial support for the project is not likely to be achieved without an exclusive license;

(4) exclusive licenses shall require reasonable and continuous effort by the licensee to advance the invention to the market and be limited to the time necessary to allow for recoupment of investment by the licensee;

(5) royalties be used for educational or research activities of the Center;

(6) the Center make periodic reports to the Director, and the Director may treat information contained in such reports as privileged and confidential technical, commercial, and financial information and not subject to disclosures under the Freedom of Information Act; and

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(7) any Federal department or agency shall have the royalty-free right to practice, or have practiced on its behalf, the invention for governmental purposes.

The Secretary shall obtain title to any invention for which this option is not exercised.

SEC. 7. GRANTS AND COOPERATIVE AGREEMENTS.

(a) IN GENERAL.—The Director may make grants and enter into cooperative agreements according to the provisions of this section in order to assist any activity established under section 6 of this Act. The total amount of any such grant or cooperative agreement may not exceed 75 percent of the total cost of the program or project involved.

(b) ELIGIBILITY AND PROCEDURE.—Any person or institution may apply to the Director for a grant or cooperative agreement available under this section. Application shall be made in such form and manner, and with such content and other submissions, as the Director shall prescribe. The Director shall act upon each such application within 6 months after the date on which all required information is received.

(c) TERMS AND CONDITIONS.—

(1) Any grant made, or cooperative agreement entered into, under this section shall be subject to the limitations and provisions set forth in paragraphs (2) and (3) of this subsection, and to such other terms,

conditions, and requirements as the Director deems necessary or appropriate.

(2) No payment under any grant or cooperative agreement under this section may be applied to the purchase or rental of any land, or the purchase, rental, construction, preservation, or repair of any building.

(3) Any person who receives or utilizes any proceeds of any grant made or cooperative agreement entered into under this section shall keep such records as the Director shall by regulation prescribe as being necessary and appropriate to facilitate effective audit and evaluation, including records which fully disclose the amount and disposition by such recipient of such proceeds, the total cost of the program or project in connection with which such proceeds were used, and the amount, if any, of such costs which was provided through other sources. Such records shall be maintained for at least 3 years after the completion of such a program or project. The Secretary, Director, and the Comptroller General of the United States, or any of their duly authorized representatives, shall have access, for the purpose of audit and evaluation, to any books, documents, papers, and records of receipts which, in the opinion of the Secretary, Director, or the

Comptroller General, may be related or pertinent to such grants and cooperative agreements.

SEC. 8. ADMINISTRATIVE ARRANGEMENTS.

(a) COORDINATION.—The Director shall, on a continuing basis, seek the advice and cooperation of departments and agencies whose missions contribute to or are affected by the programs established under this Act, including the development of an agenda for research and policy experimentation. These departments and agencies shall include but not be limited to the Departments of Defense, Energy, Health, Education, and Welfare, Housing and Urban Development, the Environmental Protection Agency, National Aeronautics and Space Administration, National Science Foundation, Small Business Administration, Council of Economic Advisers, Council on Environmental Quality, and Office of Science and Technology Policy.

(b) AUTHORIZATION.—The Secretary is authorized to receive moneys from other departments or agencies to support activities of the Centers established under section 6 and for the support of studies and policy experiments. A major portion of the studies and policy experiments shall be conducted under grants and contracts.

SEC. 9. INDUSTRIAL TECHNOLOGY REVIEW PANEL.

(a) ESTABLISHMENT.—There shall be established an independent committee to be known as the Industrial Technology Review Panel.

(b) DUTIES.—The Panel shall take such steps as may be necessary to review annually the activities of the Office and advise the Secretary and the Director with respect to—

(1) the formulation and conduct of activities under section 5 of this title;

(2) the designation and operation of Centers and their programs under section 6 of this Act;

(3) the preparation of the report required under section 5(d); and

(4) such other matters as the Secretary or Director refers to the Panel for review and advice.

The Director shall make available to the Panel such information, personnel, and administrative services and assistance as it may reasonably require to carry out its duties.

(c) MEMBERSHIP, TERMS, AND POWERS.—

(1) The Panel shall consist of 15 voting members who shall be appointed by the Secretary. The Director shall serve as a nonvoting member of the Panel. The members of the Panel shall be individuals who, by reason of knowledge, experience, or training are especially qualified in one or more of the disciplines and fields dealing with technology, labor, and industrial in-

novation or who are affected by technological innovation. The majority of the members of the Panel shall be individuals from industry and business.

(2) The term of office of a voting member of the Panel shall be 3 years, except that of the original appointees, five shall be appointed for a term of 1 year, five shall be appointed for a term of 2 years, and five shall be appointed for a term of 3 years.

(3) Any individual appointed to fill a vacancy occurring before the expiration of the term for which his or her predecessor was appointed shall be appointed only for the remainder of such term. No individual may be appointed as a voting member after serving more than two full terms as such a member.

(4) The Panel shall select a voting member to serve as the Chairperson and another voting member to serve as the Vice Chairperson. The Vice Chairperson shall perform the functions of the Chairperson in the absence or incapacity of the Chairperson.

(5) Voting members of the Panel shall receive compensation at a daily rate for GS–18 of the General Schedule under section 5332 of title V, United States Code, when actually engaged in the performance of duties for such Panel, and be reimbursed for actual and

reasonable expenses incurred in the performance of such duties.

SEC. 10. AUTHORIZATION OF APPROPRIATIONS.

(a) There is authorized to be appropriated to the Secretary for purposes of carrying out section 6, not to exceed $40,000,000 for the fiscal year ending September 30, 1980, $50,000,000 for the fiscal year ending September 30, 1981, and $60,000,000 for each of the fiscal years ending September 30, 1982, 1983, and 1984.

(b) In addition to authorizations of appropriations under subsection (a), there is authorized to be appropriated for purposes of carrying out the provisions of this Act, not to exceed $10,000,000 for each of the fiscal years ending September 30, 1980, 1981, 1982, 1983, and 1984.

(c) Such sums as may be appropriated under subsections (a) and (b) shall remain available until expended.

Senator STEVENSON. We have four witnesses this morning, and I would like them all to come forward. They are Dr. Herbert Hollomon, director of the center for policy alternatives at MIT; Dr. Jack E. Goldman, group vice president and chief scientist of the Xerox Corp.; Mr. Monte Throdahl, vice president of Monsanto; and Dr. Carver Mead, associate director of Computer Sciences Laboratory at the California Institute of Technology.

Please join us, gentlemen. We will proceed with your statements, and we will come back to you—all of you—with questions. I say "we" advisedly, because I am told that Senator Schmitt is on his way, and we may have other members this morning.

Dr. Hollomon, if you have no objection, let's proceed with your statement. I will invite all of you to summarize and if you do, I will enter the full statements in the record.

Please proceed.

**STATEMENTS OF DR. J. HERBERT HOLLOMON, DIRECTOR, CENTER FOR POLICY ALTERNATIVES, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.; DR. JACK E. GOLDMAN, GROUP VICE PRESIDENT AND CHIEF SCIENTIST, XEROX CORP., STAMFORD, CONN.; MONTE THRODAHL, VICE-PRESIDENT, MONSANTO CO., ST. LOUIS, MO.; AND DR. CARBER MEAD, ASSOCIATE DIRECTOR, COMPUTER SCIENCES LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIF.**

Dr. HOLLOMON. Thank you, Mr. Chairman. I have a very brief statement which I would like to read and then respond to any questions that you have.

Senator STEVENSON. All right.

Dr. HOLLOMON. Obviously, it is a pleasure for me to be here after having been concerned about this problem for nearly 20 years. I would like to speak to the importance of technology to the country, some of the problems, and some of the reasons why we have not dealt with the issues sooner.

And, finally, along the lines of your comments, I'd like to make some suggestions as to other areas of importance which this bill does not address.

The introduction of new and improved products and services, sometimes derived from advances in science and technology, provides an important basis to meet the needs of society, increase the productivity and wealth of the Nation and enhance the health and welfare of its citizens. At times the widespread production and use of new goods may lead to consequences that adversely affect society. Other innovations, on the other hand, may alleviate these same adverse effects. The new displaces the old—coal substitutes for wood; oil for coal. The modern automobile is the horseless carriage. Old industries may disappear; regions of countries may become depressed; companies fail and workers lose their jobs. Yet innovation is fundamental to the growth of economies. All nations—rich and poor—are concerned about conditions that foster it, and at the same time are anxious to assuage the possible harmful consequences of widespread use of the new.

Except for the efforts of a few scholars and other concerned individuals, the nature of the innovation process and the conse-

quences of technological innovation have received little attention in the United States until recently.

Several factors explain this. There had been spectacular successes of new weapon developments, such as radar and nuclear arms, during World War II, and scientists had been mobilized and liberally supported without concern for costs. After World War II the United States was the strongest Nation on Earth—politically, militarily, and economically.

There was a pent-up demand for consumer goods unavailable during the war. Europe and Japan had to be rebuilt.

Most observers believed that the Nation's vigorous R. & D. effort would automatically produce the new goods and services needed for improvement of the health, welfare, and quality of life of the American people. The technical progress in the United States and the astonishing advances in nuclear energy, aircraft, and computers—spinoffs directly or indirectly from the space and defense program—inspired other nations to intensify support for research, to create special science ministries, and to become apprehensive about the technological gap between their countries and the United States.

Macroeconomic tenets dictated the country's policies, even though they often yielded unreliable predictions and generally ignored the realities of how industrial goods and commercial services are actually developed and delivered. There was little concern with the details of industrial practice or with the system of providing goods, and almost no comparative analysis of how technology is developed and used in different industrial sectors. It was considered enough to insure demand.

In the early 1960's a number of people, mostly with industrial experience, but joined by a few scholars learned in industrial practices, first began to question the wisdom of the then prevailing attitudes. Their emphasis was on microeconomic analysis and the need for policies directed more precisely toward the problems of individual firms and sectors of the economy. As an Assistant Secretary of Commerce, I encouraged analysis of the significance of the innovation process—the well-known Charpie report was a result. Little action resulted in the United States in response to the recommendations of that report. However, other nations began to understand and appreciate the importance of innovation and to perceive R. & D. as only one part of the complex process required to bring the new into practical and widespread use.

By the 1970's it had become clear to many people that something was amiss. Productivity improvements in the United States were and had been for 20 years less rapid than those in every Western country except the United Kingdom. The imbalance of trade between the United States and the rest of the world had become huge. Even though Japan and West Germany imported relatively more oil than the United States they still had been able to maintain a favorable balance. The people of four industrialized nations—West Germany, Sweden, Switzerland, and Norway—had become more affluent than the people of the United States. Americans had recognized the need to improve safety, health, and environmental quality. They had noted the deteriorating quality of U.S. products—dramatized earlier by the recall of millions of faulty

automobiles and more recently the failure of a nuclear reactor and the DC–10 airplane. It became apparent that the strong U.S. policy emphasis on R. & D., even now still only slightly less than one half of the world's total, had not produced the results its earlier proponents had proclaimed.

In my view, what was—and what still is—needed are policies that encourage the innovation process, not just R. & D., in order to be broadly responsive to the problems above. The introduction of new technology is an important means of improving U.S. competitiveness in foreign trade—as shown by favorable trade balances in technology-intensive manufacture and unfavorable balances in other manufactured goods. Similarly, introduction of the new leads to improvements in productivity. The subsequent spread of new technology through the economy, that is diffusion, can lead to general improvements in the quality of goods—for example, much of the pollution abatement effort is being accomplished with existing technology—and this improved quality leads to further productivity gains.

What exactly is this innovation process that we wish to encourage? First of all, it is not the same as R. & D.—a lesson that is by now well-learned as a result of mistakenly equating R. & D. with innovation among policymakers. Rather, the process of innovation usually begins with a new concept of a product, process, or service. This is followed by R. & D. A preliminary design is developed, tested by a user, and modified before the final version is purchased and diffused into widespread use. These steps require inventors, ingenious engineers, entrepreneurs, risk capital, a knowledge of the market, and finally, the spread of the new thorough education and training. We have not appreciated the complexity of the process.

There are many social ramifications resulting from the introduction of a new technology and many different conditions that can foster innovation. I believe that rivalry and competition, risk, entrepreneurship, and creative engineering are considerations crucial to the process. It must be recognized by policymakers that innovation among small firms and individuals is different from that in large institutions. These groups need special nurturing, but their needs have, as yet, received little attention. Similarly, the diffusion of know-how to small and medium-sized firms is crucial to our competitive position.

I further believe that challenge and response are essential for a dynamic society, that there must be rewards for the risk taker, and that the protection of the status quo will only stifle innovation. Some will, of course, be hurt by change, and any resulting adversity to these people must be shared by the whole. It is important to help people adjust to the new opportunities and not to be resigned to the old. Similarly, it is important to protect people from the sometimes adverse consequences of the new. Regulation is one way this is done. Regulation need not hamper innovation; indeed, safety and health requirements, discriminatingly applied, can be a spur.

Innovation will, of course, come largely from the private sector. Nevertheless, Government too has an important role to play as overseer, regulator, funding source, or catalyst for actions that the private sector cannot be expected to initiate on its own. Private firms simply cannot oversee or coordinate the technological needs

of the country—nor, if they could, would we be sure that the public interest would be served. Moreover, there are many activities, particularly in reasearch, that are of important benefit to society in general but which individual firms will not undertake because they cannot capture enough of the economic benefits to justify the investment.

Governments in virtually all the industrialized nations have realized this. Most have initiated explicit programs and policies to encourage innovation for civilian purposes, as well as programs of general support for the technology that undergirds the process of innovation. These programs fall into five broad categories: (1) Analysis of the technological needs and competitiveness of specific sectors—for example Japan's Ministry of International Trade and Industry; (2) support for generic industrial technology—a $250 million per year effort by the Federal Republic of Germany; (3) direct financial support to individual firms for new product development—the French Aid to Development program; (4) general technical assistance—industry research associations in the United Kingdom; and (5) special assistance to small and new firms—an element of every program in Japan. Even though—may I interpose—even though we may consider the Japanese competitiveness being based on large, dynamic firms, the Japanese Government has the most complete and complex assistance for the startup of small firms of any country in the world. These programs are only examples and are not meant to suggest specific actions to the United States. I mention them primarily to show that the activities suggested in S. 1250 are an appropriate and necessary governmental function, and have been recognized as such in other highly industrialized nations.

Unless old perspectives and attitudes are changed, U.S. competitiveness will be further weakened. We must reverse the direction of some of our past practices, and recognize that the effective use of industrial technology is crucial to our wealth, health, and security. New programs are needed. The general thrust of this legislation is clearly in the right direction.

As I see it, this legislation has three major purposes. The first is to mandate an office within the Commerce Department to be responsible for overseeing the relation between technology and the economic and social well-being of the United States. There are entire departments concerned with natural resources, food, energy, and labor, but not until this legislation has the Congress specifically charged an agency with the responsibility for industrial technology. This is an important first step. It recognizes that technology has become the crucial renewable resource for industrial development.

The second objective of the legislation will also be accomplished by the new office. This is to provide the data, analysis, and judgments necessary for intelligent decisions to enhance the development of technology and innovation. It is remarkable that a country that spends so much on R. & D. has not seen fit to examine in detail how technology influences the trade, economic behavior of the United States, or how specific industrial sectors develop and use technology.

The studies proposed in the legislation should provide an important aid to decisionmaking both in Government and in private firms. For the Government, the studies should help establish better bases for trade, antitrust, and patent policy. For private firms, the studies should often be of assistance in formulating market strategies, for example, in international trade and investment.

The third objective of the legislation is to support the technology broadly applicable to industrial development, which, according to all pertinent economic analysis, is undersupported in the United States. Such technology is undersupported by private firms because they cannot appropriate all of the social benefits that arise from it. These social benefits have been shown generally to exceed development costs. In accomplishing this objective, the new office would support the development of new ideas, the spread of nonproprietary know-how, and support education for would-be innovators and entrepreneurs.

I have little to suggest with respect to establishing the new office or the studies with which it is to be charged. These studies should be supported by contracts and grants with competent people and institutions throughout the United States and not be performed solely within the Government. We need pluralistic view in this complex area and we need to develop within the United States the competence to analyze and provide advice on policies regarding industrial technology and innovation. And the expertise should not reside wholly within the Government agency. This competence must be fostered both inside and outside of the Government.

With respect to the direct support for activities to encourage the innovation process, I'm somewhat more critical, not that the activities of section 6(b) are not needed, but rather that they apparently will be supported only in new centers that will have to be created. While some new institutions might be needed, I see no reason why support could not be provided for these purposes to existing organizations and structures. The time required to establish these centers and the new bureaucracy they generate may be unnecessary.

I do not believe that it will ever be possible to place the activities described in section 6(b) on a self-sustaining basis. Smaller and new firms, who are likely to be the major clients of the centers, will find it difficult to provide funds. This means that without Government support the centers may fail financially or be forced to rely on large companies for financial backing. Rather, I think that the Office of Industrial Technology should judge the need for continuing support of these activities in the future on the degree of industrial support that develops and not necessarily that they are self-sustaining.

The establishment of these centers should begin the process of changing the university-industry relationship. University research has in the recent past not been well matched to the needs of industry. Or put another way, they have been well-matched only to a narrow sector of industry. Partly this is because Government funding for university research was concentrated in areas like space research, which does not have direct applicability to most firms' needs.

One of the important aspects of these centers' impact will come through the people hired to staff them. These individuals will be

devoted to the problems of industrial technology, rather than, for example, basic scientific research, and will bring a new orientation to the university. They may function much like individuals connected with the agricultural extension program in universities, an effort which is analogous in several important respects to that proposed in this legislation.

While the activities of the proposed legislation are valuable, they are not enough to insure the great improvement in the climate for innovation that is needed. As you have said, Senator, upon introduction of this bill, more needs to be done—this legislation is only a beginning.

In a study prepared for the OTA by the center which I direct, we described a series of steps which we believe the Congress should consider to deal with the entire question. They are described in detail in the OTA report.

These steps are:

Direct support of nonmission-oriented technology—technology of broad commerical and social applicability, financially supported through various Government initiatives.

Reconsideration of the role of the national laboratories and the appropriateness of their current missions, especially as they relate to developments in the private sector.

Facilitating new entrants into the market, through means such as venture capital, tax benefits, et cetera, in order to encourage the introduction of innovative technology.

Diffusion of technology within the private sector, that is, better application of existing knowledge to current problems, especially those of small firms, through means such as those provided in this act.

Implementation of environmental and safety regulations with a new emphasis on innovative changes in technology as the key to cost-effective solutions and the achievement of regulatory goals.

Manpower resources, the labor market, and technology—an emphasis on the improvement of labor skills as an input to innovation and as a means of ameliorating the adverse consequences of technological change.

International commerce and domestic innovation—an understanding of the role of technology in international trade and specific initiatives to improve the position of U.S. industries in world markets.

Support for hazard analysis—systematic efforts to uncover potential environmental, safety and health hazards, to prevent them before they occur.

Affecting the demand for new technologies—new policy initiatives that focus on consumer demand and demand-inducing mechanisms—such as government procurement—rather than simply attempting to increase the supply of new technical ideas.

This legislation deals with at least three of these issues, and I hope that in the future the Congress will consider those other ones that are also important.

Thank you, Mr. Chairman.

Senator STEVENSON. Thank you, sir.

And Dr. Goldman?

Dr. GOLDMAN. Thank you, sir. I have some written comments which are presumably on the record, and I will not read them. I would rather summarize the thoughts that I have therein and a few additional ones for the purposes of discussion this morning.

In my written testimony I cited a few examples of innovations that most of us have lived through in our lifetimes. I cited the example of the invention of the transistor and of the revolution in the electronics world that invention has given us and concommitent advantages in international trade today; I also have cited the invention of the core memory.

I would add to that the evolution over the past 40 or 50 years of the U.S. airframe and aircraft—commercial aircraft—industry, for reasons I will come to a little later.

A characteristic of these and so many other innovations that comes to mind when we try to run through a sequence of innovations that have been of decided economic advantage is that, contrary to the popular image, an innovation does not usually result simply from a light suddenly switching on in the mind of an inventor one night when he can't sleep. Innovations tend to be the product of a series of processes and often begin with the basic work done in university laboratories, translated ultimately into applied research, and then a whole chain of pulling mechanisms in the marketplace, and the infrastructure that this country possesses for manufacture and cost reduction in the process of manufacture.

Let us take the example of the invention of the transistor. While the Nobel Committee quite properly saw fit to award a Nobel Prize to Drs. Brattain, Shockley, and Bardeen for having invented it in the Bell labs in 1947, in point of fact, this was the end results of a series of events, many of which took place on university campuses.

It is well-known in the art—and I'm sure that Professor Mead will later confirm this—that much basic work done in such institutions as Purdue University, MIT, and the University of Pennsylvania, were leaned on very heavily by the inventors of the transistor. A good deal of science is at the root of the evolution of the whole industry of microelectronic chips and microprocessors. Much of this work was done at universities.

Now, we see a trend today that many of us find very alarming: namely that the interactions between industries and universities have decreased rather perceptibly over the last decade and a half. And evidence thereto is given in my paper—in the written testimony, in a chart citing data which came from the National Science Foundation, on the ratio of Federal to industrial support of R. & D. in universities and colleges.

And to the extent that this is a measure of the degree of interaction between industries and universities, it says to me that this huge asset that this country posseses, a $4 billion research and development establishment in the universities, which this Nation must maintain, increase, and improve for a variety of reasons of national interest, including education, including the need to have a basic science foundation, and this asset is not being fully exploited for the total benefit of the innovative capacity of the country.

In 1960, the ratio of Federal to industrial support of R. & D. in universities was of the order of 8; by 1967 it had gone to 30.

Now, the implication here is that while R. & D. in universities has steadily progressed during that period, both in constant dollars and in real dollars, the amount that industry now puts in—that fraction of the total—is considerably less, but therefore, redress is somehow required in our society to bring industry back into that fold.

Now, this is neither the time or the place, or perhaps am I the person to go into the manifold reasons for this deterioration of the involvement of industry. In fact, the recent domestic policy review undertaken at the request of the President has considered that question rather extensively. We looked to the effects of inflation, the effects of regulation, the effects of a variety non-R. & D., nontechnical reasons, for this dillution of R. & D. involvement by industry in the universities. And the conclusion that I draw, Mr. Chairman and Senator Schmitt, is the fact that some catalyst is necessary to try to bring these two communities, so important to the innovation process, together by catalyzing involvement by industry and universities. And those provisions in S. 1250 that call for involvement between universities in industry are a step definitely in that direction.

I think there are other steps that one might consider that would bear on the overall goals of this act, such as mechanisms to match funds that industry puts in universities, rather similar to the way private foundations offer support to institutions.

The mechanism proposed for the creation of centers for industrial technology is, in my judgement, a real one, a good one, and one that is likely to attract industry large and small.

Now, clearly, the ratio of Federal funding to industry funding in a typical institute may depend on a variety of circumstances, including one alluded to by my predecessor in this chair, Dr. Holloman, who referred to the fact that small industry will often not be in a position to afford as much as large industry. And I believe this problem has to be taken into account. I think there are alot of parameters that must be worried about before we write in calmly the proposals that are included in this bill, S. 1250.

One issue of great importance to many of us in industry is the question of exclusivity of the rights gained under programs undertaken by these institutes and the recoupment of investment as written in the bill.

There is a great deal of risk being taken by industry. Not only financial risk but there are the costs of precious time, human resources and opportunities lost. Industry expects a return on its investment, not just recoupment. And I think it's to the interest of the country at large to see innovations take place, no matter how they do, and for the Government to stimulate them by offering this exclusivity.

I suspect Mr. Throdahl will address this in greater detail.

Finally, Mr. Chairman, I would like to cite one example that I think has set for us a tone for the kind of activites which could lead to U.S. preeminence in a given technology or a given industry.

I refer back to the example I mentioned of the aircraft industry. At the end of World War I, the United States was at the bottom of the development of the aircraft industry. We were behind such countries as the United Kingdom, the Soviet Union, and Germany.

Between World War I and today, we have reversed that. The United States is at the top., I think the aircraft industry owes a great deal to a concept that evolved here in Washington during the late 1920's, early 1930's, called the National Advisory Committee for Aeronautics, the precursor of NASA. The National Advisory Committee for Aeronautics is a unique example of cooperation between Government, industry, and academia. Its creation was in effect a commitment to oversee and undertake cooperative technology much the way you envision, Mr. Chairman and Senator Schmitt, the idea of cooperative technology centers or centers for industrial technology that concerned themselves with, not a product, but a technology—usually generic technologies that are so important for survival.

I would like us to think of the NACA as an example when we think of how we try to do this again in other areas. That may be of extreme importance to the economy of this country and to our balance of trade and to our position as an innovative society.

Thank you.

Senator STEVENSON. Thank you, sir.

[The statement follows:]

STATEMENT OF JACOB E. GOLDMAN, SENIOR VICE PRESIDENT AND CHIEF SCIENTIST, XEROX CORP.

Mr. Chairman, Gentlemen. My name is Jack Goldman. I am Senior Vice President and Chief Scientist of Xerox Corporation. I joined Xerox in 1968 as Group Vice President in charge of the Research & Development Group. Prior to that I was Director of Ford Motor Company's Scientific Laboratory. I also spent five years (1950–1955) on the faculty of the Carnegie Institute of Technology (now Carnegie-Mellon University) where among other activities I headed the Laboratory for Magnetics Research. During my academic tenure I also engaged quite actively as a consultant for various industrial and government activities including the U.S. Steel Company, Allis-Chalmers and both Oak Ridge and Brookhaven National Laboratories. Most recently, I served as Chairman of the Panel on Direct Federal Support of Research and Development as part of the Domestic Policy Review conducted for the White House by the Department of Commerce. As you can see I have had a long and extensive background in industrial research and development and the innovation process and have been involved on both sides of the industry/academic interface.

Permit me, if you will, some brief personal reminiscences. I started my professional career doing post-graduate research in the field of semiconductors. This was in the early forties when even the word "semiconductor" was newly coined and modest efforts were underway in a few institutions—academic and industrial—to effect a better understanding of the unusual properties of a few materials—among them germanium and silicon—that were neither metal nor insulator but had some of the properties of each. Under the impetus of the war effort—specifically the radar program—intensive efforts directed at understanding these generic materials more comprehensively were initiated at various academic and industrial centers including Purdue University, University of Pennsylvania and MIT on the academic side and Bell Labs, GE Research Laboratories and Westinghouse on the industrial side. In 1947 the transistor was invented at Bell Labs and within a few years there emerged the industry of solid state electronics that has given us the explosive technology that has made possible all those goodies that we now take for granted as: transistor radios and TV, computors, calculators, and electronic watches and now in 1979 we see no end to the ability of this technology to invade and capture more and more products and processes and—more importantly—improve very significantly their economics and reliability. But the critical factor in the rapid emergence of this technology had been the interaction between the industrial and academic practitioners of this science. It is no secret, for example, that the work at Purdue played a very vital role in stimulating the Bell invention.

Let me move on to another generic field in which I have some familarity having been an active researcher therein from 1943 to 1955: magnetism. Magnetic materials have been important in industrial technology since the invention of the electric generator and the electric motor. They are the mainstay of that industry and

beyond that have been employed extensively in transformers, instruments, relays the switches. Nevertheless, in the early 1940's there was relatively little activity in the laboratories of this country directed toward achieving fuller understanding of magnetism. The first post-war International Conference on Magnetism held at Grenoble in 1950 had fewer than ten Americans participating. But in the fifties—again motivated to a significant extent by the military potential of utilizing magnetic effects in such applications as undersea warfare, microwaves and magnetic detection, such agencies as the Office of Naval Research, the Office of Scientific Research of the Air Force and the Signal Corps of the Army seeded many research programs in university and industrial laboratories aimed—as in the case of semiconductors—at broadening the knowledge base of these materials. And then came a significant invention—this time from MIT—the core memory. Perfection of the core memory which drew upon the lore and knowledge developed at the many academic and industrial laboratories here and abroad supported by government and industry made possible the electronic computer as we know it today. The technology was transferred very rapidly to the computer industry and subsequent parallel efforts in industry and universities enabled refinement and advancement of the technology.

I selected these two examples because I have lived through both as an active participant but there are other parallel ones that can be cited—such as lasers, synthetic diamonds, synthetic fibers and antibiotics—where parallel and interactive work in industry and academia helped catalyze major innovations.

While it is risky to generalize from a few selected examples, the weight of evidence from a study of a spectrum of innovations that have had wide technological and economic impact points to the very significant function in the innovative process played by the availability of knowledge and people not just within the innovating organization but outside it as well and most often at universities. The process whereby this occurs takes on many and sometimes circuitous forms. It may happen just through the cursory reading of a publicly available professional journal—as did, in fact, occur when a research executive at The Haloid Company read about the development of the xerographic process—or it may occur through the operation of the old boy network at technical meetings. But most often it occurs both intra-organizationally and inter-organizationally by the direct involvement and movement of people. Whichever way it is accomplished, a major catalyst in the process is the strong coupling of the industrialist to the scienific and technological world around him—particularly to academic institutions.

It is this coupling between industry and unviersities that has suffered a distinct weakening in recent years. To the extent that Research & Development (R. & D.) in the universities of the U.S. contitutes an estimated $4 billion resource that is relatively untapped by the principal innovative sector of the economy—large and small industry—creating mechanisms to improve this coupling must somehow influence the innovative process.

A measure of the relative weakening of the links between industry and universities is afforded by the following statistical analysis of support of R. & D. in universities conducted by the National Science Foundation. The percentage of R. & D. support at universities from Federal and industrial sources attributable to industry which stood at approximately 12 percent between 1953 and 1960 declined sharply to 3 percent in 1966 and has since been increasing slowly and was 5 percent in 1977. To the extent that support of R. & D. by industry at universities is a measure of the degree of coupling between these two sectors, and unless that type of coupling is being replaced by other forms, that ratio must be of great concern. Exhibits 1 and 2 show the NSF data supporting the above assertion. It is of interest to point out that between 1960 and 1970 when Federal support of R. & D. at universities increased nearly fourfold, industrial support held constant and the modest increase since then has barely kept up with inflation and the increased cost of carrying on R. & D.

The reasons for this trend are many and varied and constitute a major part of the recent Domestic Policy Review initiated by the White House but in substance has to do with the pressures on the industrial R. & D. dollar resulting from inflation, interest rates, regulation, environment and safety requirements, etc. This has translated into substitution of short term profitability goals for longer term growth objectives on the part of a major fraction of industry.

If our industrial society is to tap the huge resource of university R. & D., artificial stimuli will have to be provided that will recreate the intense coupling between these two communities that was prevalent in the fifties.

We recognize that there is a qualitative difference between the type of R. & D. that is generally pursued in universities and that which is typical in industry. The former is more basic, publishable, generic; the latter tends to be applied, proprietary and product or process specific. Of course, some of the larger industrial entities continue to undertake basic research—particularly where it is relevant to the

product needs of the company—and many universities have had involvements in applied research, most notably in the engineering schools and laboratories operated by universities under contract with the government. But the incidence of a full spectrum of R. & D. that extends from the basic research through exploratory and advanced development and on to feasibility demonstration under a single institutional management is encountered only rarely in the few large sophisticated industrial establishments and perhaps one or two nonprofit research institutions.

What role can the government play in catalyzing the innovation process through greater utilization of a resource that the government is supporting anyway and without encroaching upon the proper roles and functions of the private sector. I would submit, Mr. Chairman, that a proper first step is to induce industry to become more directly involved in the university R. & D. establishment. Since experience has taught us that on the one hand such involvement is conducive to innovation but that on the other hand near term pressures within industry has caused a deprioritization of this commitment on the part of industry, it might be appropriate for the government to involve industry more directly in the allocation and evaluation of federally-funded university R. & D. programs. To do this without compromising the integrity and goals of academic research requires the establishment of a series of ground rules that will at one and the same time enhance the involvement of industry but at the same time not subvert the primary functions and prerogatives of universities. The concept of creating at universities centers for generic technology is one approach that some of us find particularly attractive and is basically what is proposed in S. 1250 as Centers for Industrial Technology.

Universities have often been the breeding grounds for new scientific and technical ideas before they are embodied in useful technologies. To make the transition from science to technology is more easily and smoothly accomplished if one does not have the additional barriers of organizational and geographical transition as well. More importantly, when a new technology is born it is too early to identify clearly the precise product or process embodiments. Hence delay is likely before an industrial enterprise committed to a specific marketplace or product line would be prepared to pick it up. Yet it is clearly in the interest of industry to see that the technology is kept alive so that it can be tapped when the conditions are ripe. Illustrative cases are computer control of manufacturing processes, synthetic polymeric materials, computer assisted design and education and cryogenic threshhold devices, not to mention the host of technologies involved in energy production, pollution and safety.

Our laws and our culture prevent industries from agglomerating in order to support jointly promotion of technology advances as is the practice in Japan and Western Europe. The mechanism proposed in S. 1250 accompanied by appropriate safeguards to assure free competition makes it possible to accomplish this goal in a manner that does justice to the spirit of free competition while encouraging the evolution of technologies that may not be readily promoted by individual companies or may be too early in the development cycle to assure profitable exploitation.

I would be remiss, however if I did not point out one pitfall that must be cleared up if the creation of such Centers is to have the desired effect. This has to do with availability and exclusivity of patent rights. For industry to have the incentive to participate and to allocate its precious manpower and/or monetary resources and anticipate the prospect of investment in the embodiment of new technologies in products and processes, it must have a clear road to proprietary exclusivity beyond simply recoupment of its investment. I think the recent history of technological innovation in the United States has clearly demonstrated that when innovation is stimulated—no matter who does it, who supports it or who pays for it—the increased wealth promoted thereby, the new job opportunities created and the opportunity to redress the balance of trade, returns to the government and its taxpayers far more than the original contribution.

EXHIBIT 1

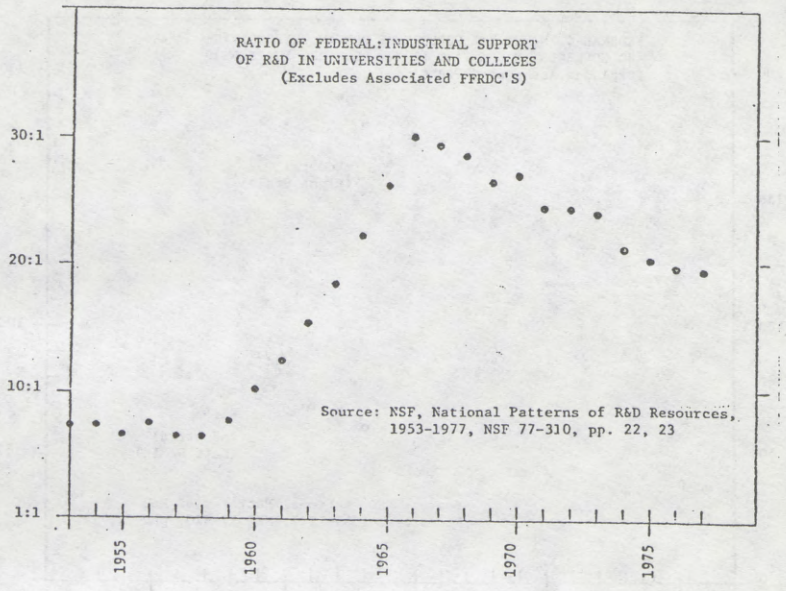
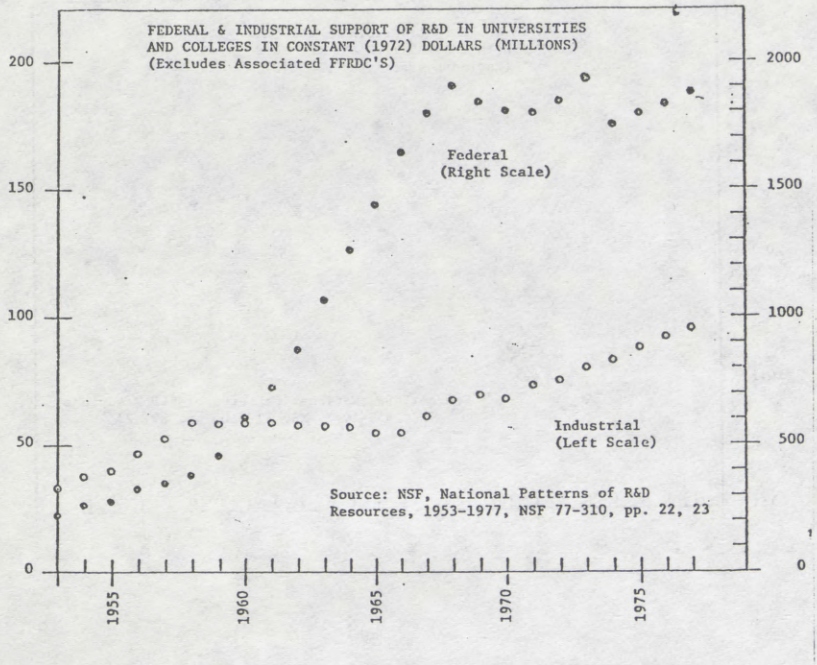

RATIO OF FEDERAL:INDUSTRIAL SUPPORT
OF R&D IN UNIVERSITIES AND COLLEGES
(Excludes Associated FFRDC'S)
30:1
20:1
10:1
1:1
1955
1960
1965
1970
1975
Source: NSF, National Patterns of R&D Resources,
1953-1977, NSF 77-310, pp. 22, 23

EXHIBIT 2


FEDERAL & INDUSTRIAL SUPPORT OF R&D IN UNIVERSITIES
AND COLLEGES IN CONSTANT (1972) DOLLARS (MILLIONS)
(Excludes Associated FFRDC'S)
Federal
(Right Scale)
Industrial
(Left Scale)
Source: NSF, National Patterns of R&D
Resources, 1953-1977, NSF 77-310, pp. 22, 23
200
150
100
50
0
2000
1500
1000
500
0
1955
1960
1965
1970
1975

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

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
*Washington, D.C., June 26, 1979.*

Dr. J. E. GOLDMAN,
*Senior Vice President and Chief Scientist, Xerox Corp.,*
*Stamford, Conn.*

DEAR DR. GOLDMAN: I wish to extend my appreciation for your most informative testimony on S. 1250 before the Science, Technology, and Space Subcommittee. After reviewing the testimony of all the witnesses during our June 21 hearing, I would greatly appreciate your responding to the following additional questions. Please address your reply to Mike Crisp of the Senate Committee on Commerce, Science and Transportation Minority Staff, DSOB 5102, Washington, D.C. 20510. If you reply is received by July 15, there will be no difficulty including it in our hearing record.

1. Does the prospect of two companies, that are competitors within the same industry, contributing funds and personnel for a joint research project at one of the Centers for Industrial Technology present any potential antitrust questions? If antitrust problems are anticipated, what needs to be done to avoid these problems?

2. Does S. 1250 contain sufficient incentives to insure significant participation of industry in the Centers for Industrial Technology Programs? What are the most important incentives contained in S. 1250? Can you suggest any changes in S. 1250 that would increase the incentive for private sector participation?

3. What is the annual research and development budget of your company? Do you think the $40–60 million authorized for the Centers for Industrial Technology in S. 1250 will make a measurable contribution to innovation throughout the United States?

4. The bill S. 1250 has a provision which would allow issuance of an exclusive patent license if industrial support or commercialization requires it. Who do you think should decide that an exclusive license is required? Are the patent provisions of S. 1250 appropriate for the Centers?

5. The bill S. 1250 discusses the commercialization of inventions that are developed at the Centers for Industrial Innovation. At what stage in the "commercialization" process should the Center step aside and let the private sector take the product the rest of the way to the market place?

6. The bill S. 1250 creates the Office of Industrial Technology within the Department of Commerce. This office will serve as the focus for innovation policy in the United States government. Do you feel that it would be appropriate for this office to perform the function of scruntinizing federal regulations and tax policies that are identified as serious impediments to innovation in the private sector? Can you suggest any changes in S. 1250 that would make the Office more effective in combating burdensome regulations and inappropriate tax policies that are barriers to innovation?

Once again, I would like to thank you for taking the time to present testimony during our June 21 hearing on the National Technology Innovation Act.

Sincerely,

HARRISON H. SCHMITT, *U.S. Senator.*

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XEROX CORP.,
*Stamford, Conn., August 28, 1979.*

Hon. H. H. SCHMITT,
*Committee on Commerce, Science, and Transportation,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR SCHMITT: In response to the questions in your letter of June 26, 1979:

1. Your question of potential antitrust questions arising when two or more competing companies support a joint research project is one that I do not feel competent to respond to without benefit of antitrust counsel. I, therefore, ask to defer my response to this question to a later date.

2. While I agree in principle with the goals of S. 1250 and the mechanisms set up to achieve these goals, I don't believe the incentives for industry to participate are great enough. There are two classes of incentive that must be addressed: one is the financial incentives that causes industry's stake to become sufficiently leveraged that it is motivated to expend time and resources to participate. The second has to do with the ability of a participating company to take to market any potentially

proprietary output. To this end exclusivity is required beyond that called for in S. 1250, i.e., until the original investment is recovered.

3. My company will spend in 1979 $385 million on research, development and engineering. Most of this is geared toward identified product goals and technology support to assure that these products are reliable, maintainable and offer the finest quality and economics in our industry. You ask whether the $40-60 million called for in S. 1250 for the Centers for industrial Technology is sufficient. I view this investment by the government as an experiment which will necessarily be limited by the funds available to a few selected industry candidates that will be carefully chosen. If success of the experiment is indicated, I am sure the Congress will be prepared to expand upon it; if not, we should at least know why before we continue the funding. I urge caution, however, in expecting results too soon. The cycle from research to product may take from 7 to 10 years. But I would expect by year 3 or 4 we should have a good handle on whether we are on the right track.

4. As mentioned earlier, for industry to be motivated to participate in the Centers and to expend the resources necessary for follow-on activities that could promote inventions originating in the Centers to innovations, it must be assured of a degree of exclusivity far beyond that provided for in S. 1250. The bill purports to give exclusivity until the company's investment is recovered. This would not be considered by industry an appropriate incentive. Because of inherent risk factors in R&D investments and the discounted present value of earnings realized in later years through R&D investments today, industry must expect to retain an exclusive position over a period considerably longer than that required to recoup its initial outlay. It may require some form of competitive bidding among participant companies to determine the exact terms of patent allocations, but this too may have antitrust implications which I do not feel competent to address, but which will be considered in the subsequent letter on antitrust questions.

5. The Center should carry a program to the point where feasibility of product or process function is demonstrated. Scale-up, pilot plant, engineering and manufacturing prototypes should be the province of the participating company. It may turn out that to stimulate the innovation process incentives will have to be provided as well for those steps and there well may be initiatives developed by the Congress through the government procurement process or other alternative means. But that should not be confused with the principal missions of the Centers which should be to seek a means to provide relevant generic technology.

6. Indeed, I do believe that it would be useful to focus within a single office in the Department of Commerce responsibility for monitoring the state of health of U.S. industrial technology, supervising the initiation of new government incentives to stimulate innovation such as the proposed Centers for Industrial Technology and take the leadership on behalf of the government in developing policies to overcome other barriers to innovation. In a way, it is a natural follow-on to the activities of the Domestic Policy Review conducted for the President by the Department of Commerce, an exercise which I consider to have been eminently successful.

I hope, sir, that these comments will be helpful to you in furthering your already effective support for a new initiative in stimulating industrial innovation as manifested by S. 1250.

Sincerely,

J. E. GOLDMAN,
*Senior Vice President and Chief Scientist.*

Senator STEVENSON. Mr. Throdahl?

Mr. THRODAHL. Thank you, Senator.

I will support the previous two testimonies better than I would have thought, although I had not seen them prior to arrriving here. The whole subject of technological innovations is becoming an end in itself, rather than a means to an end. What I would like to do today is supplement my written testimony by giving you a three-point perspective on some principles of innovation that everyone of us should try to bear in mind. The subject is a difficult one. I would also like to point out five aspects of what we believe to be a unique university-industry relationship that we have; and then, lastly, I would like to make four recommendations with regard to S. 1250.

I see innovation as a various process, like Dr. Goldman suggested, and it's of real value when the conversion closes its loop. So,

one would look then at S. 1250 and say, "Well, what incentive will this offer to academic scientists, industrial risk-takers, and to the public?"

It's my experience as one who has brought some innovations into being, I think those three points go a long way toward explaining what makes innovation happen and what makes it successful.

The first point has to do with uncertainty. I think the general consensus is that uncertainty and risk are the same, however, I submit that they're not. We understand risk a good deal better than uncertainty because we can establish some probabilistic value to the risk. But if something is uncertain, it will either happen or it won't and the outcome is very difficult to predict.

By and large, then, innovation starts out dealing with uncertainty, and that is what makes it so difficult to justify. There is no way we can predict what we will find, when it will be found, or how successful it will be. That's a very uncomfortable feeling for most people who have to supply the funds.

The second point has to do with the time factor for innovation—and that demands patience. Certainly, in the high-technology industry world, one can find averages. Ten years is not a bad order of average for an idea to become a product, although there are many more that have taken much longer. Therefore, a successful innovation is often determined by the length and consisitency of the commitment.

This long-term commitment, unfortunately, runs afoul of the usual year-to-year budgeting process that we experience in most businesses, and in Government as well. The point I am making here is that the innovative process will probably far exceed the particular job venture of a given executive who may be responsible for its ultimate success or of the individual scientists. Without that understanding, there is great disappointment.

So, two of the three points now have to do with dealing with uncertainty and dealing with patience and time. And the third point of innovation which I would note is timing. In effect, all innovations are pointed toward a moving target. No matter how good the product or the service may be the investment of both financial resources and time are going to be wasted if that innovation is not accepted by the public.

In other words, think of the relationship between the public readiness to accept something and the development of the state of the art. Where those two converge, a little window is open, and it's only open for a brief period of time. If the innovation cannot be carried out within that time frame—if it is either too early or too late—the innovation becomes less desirable.

These three principles were taken into consideration. Now I would like to move into a long-term biomedical project that we are conducting jointly with the Harvard Medical School. As I said, to my knowledge, this program is unique, and my purpose here is simply to explain it. But as I explain you will see how those three principles were brought to bear in drawing up our agreement.

I am quick to point out that this will not be for everyone. I do want to demonstrate that it's possible to have a joint project which benefits the entity that does the basic research, and to benefit the entity that takes the entrepreneurial risk—that's ourselves. And

it's possible that the consuming public can be benefited. Thus, it seems to me, we close the loop in an effective way.

So, let me review five aspects of our project with you.

The first point starts out with the fact that we were seeking a new area for possible future growth—corporate growth—and we called it a "window on biology." Even though we had been in the agricultural—plant biology—business for a long time, this biology had more to do with mammals. So while biological chemistry was becoming increasingly important to us in our business, it wasn't among the traditional lines of expertise that we had.

We sought a few superlative researchers, and we found them at this particular academic institution. The key point here, though, is that the arrangements were made with specific people in mind, rather than the institutions, although obviously they have to be someplace.

The second concept had to do then with the input to this joint arrangement. Obviously, my company was providing money, and certain kinds of technology that would be supportive of the people at Harvard. They were going along in that basic research.

The third point outlines what we hope to get out of the project. While we provided the money and technology in support of the basic research in which we were interested, we also agreed that they were free to publish, as is their custom. But we were given exclusive right for any commercialization of useful products that could grow from that research. Therefore, the quid pro quo was established.

The Harvard group will receive royalties if any patents are achieved. They have what we call "march in" rights, should we fail to commercialize a discovery within some specified period in the arrangements. That safeguards their discovery in the event that we either choose not to or do not have the capability or whatever to carry out to a full circle the results of their particular discoveries.

The fourth concept involved what I would call some "built-in guarantees" for long-term commitments. Our agreement runs for 12 years, and we're almost halfway there at this point. Termination was not permitted within the first 4 of the 12 years, and even now each side is bound to communicate to the other long in advance an intention that it wishes to bail out. There are bail-out provisions, of course.

But what I am trying to point out is that we recognized that we were going to be patient; we were going to have to go through many periods of ups and downs Saying it another way, you can't expect the innovation to flower if you keep pulling it up by its roots and looking at it.

The fifth and last point recognizes the uniqueness of this joint project, and the considerable interest that the public has in the outcome. To handle that, we created, as part of the contractual arrangement, a public advisory board. The board number happens to be five. Not one of those members have any formal connection with either Harvard or ourselves. They were selected for their ability to represent the public interest in this venture, and they are kept informed in a general manner as to the state of the program. They are at the ready, so to speak, to adjudicate any differences that we may have with Harvard over the public inter-

est aspects of our project. And we think that the balance on the board of two people who principally devote themselves to external matters and three people who devote themselves to science is perhaps as good a balance as you can find.

Now, let me turn to the four recommendations I would offer for modifying S. 1250.

First and foremost, the success of the centers of industrial technology depends on granting exclusive licenses rather than nonexclusive. Let me tell you why: Most Government-held patents today are licenses on a nonexclusive basis, but only around 4 percent of those patents have been successfully commercialized. It doesn't seem surprising.

Without the promise of some exclusivity, with appropriate march in rights, such as Harvard has with us, few companies are going to be willing to invest the kind of time, the human talents, and, obviously, the money that it will take to carry the innovation process from basic research through commercialization and on to serve the public good.

Now, I don't think you should get exclusivity for free. So, the second point I would like to make here is that in exchange for this exclusive licensing arrangement, there should be a system of royalties from successful innovations that would flow back to the Office of Industrial Technology and to the institution involved—to the centers that were involved in the project.

Now, this won't make the centers self-supporting, but it will obviate the argument that exclusivity gives an unfair advantage.

The third point is that the projects at the centers certainly ought to be funded on some sort of a renewable privilege basis for at least 3-year periods to avoid forcing the researcher to unreasonable races against time. Setting a goal of self-sufficiency for the centers would force them to pursue for the most part short-term quick-payoff projects, rather than the long-term basic research that might lead to more significant technological breakthroughs.

I think this is borne out in many kinds of contract research institutes. After all, the continuity of personnel is important. Therefore, contracts have to be sought for the time which the one that's current expires. And that consumes a great deal of energy and some psychological concern on the part of the members of the technical teams.

The fourth point is that the bill does not make clear what the centers are, what they should do, or how many are needed. And I think the bill could be strengthened appreciably if it outlined the scope that is intended. If you are dealing with a baker's dozen or if you're dealing with a hundred or more, the problems are quite different. Also Congress should make sure that it does not duplicate facilities already supported by the Federal Government. Some of those, of course, are well known in the agricultural arena.

If the primary goal of the bill is to develop products in the marketplace, to stimulate the economy, there are plenty of things to do. The whole purpose of this bill, as I see it, is to convert selected information into new products, new services, and bring those to the public. It seems to me that's a pretty good kind of game to play.

The last point I would make then would be, to show how all three sectors—the public, academic institutions, and industry—will benefit from this bill. I attempted to show how this might work in a schematic drawing attached. I have tried to show that there is a relationship between a flow back of royalties from successful innovations that are based on exclusive license. I think that's the key point of that little drawing.

Thank you very much.

Senator STEVENSON. Thank you very much. Your statement will be entered in the record.

[The statement follows:]

STATEMENT OF MONTE C. THRODAHL, SENIOR VICE PRESIDENT, MONSANTO CO.

The state of technological innovation in the U.S. today is being widely discussed in academia, industry and government—so widely discussed that we tend to start thinking of innovation as having value in and of itself. I would submit, however, that we need to keep a sense of perspective. Innovation is really the conversion of science into technology, and technology into public benefits. That's the real value of technological innovation.

Therefore, in examining the proposed National Technology Act of 1979, we have to ask how it will improve this conversion process. What incentives will it offer to both academic scientists and industrial risk-takers, and what benefits ultimately will flow to the public?

I believe this proposed bill has potential for making a very positive impact on those incentives and ultimately on public benefits. In this testimony, I will suggest some ways to make it an even stronger bill. But before getting to that, I'd like to offer a frame of reference that may be helpful in thinking about technological innovation.

In my experience dealing with both scientists and entrepreneurs, I have come to recognize three axioms that go a long way toward explaining what makes innovation happen and what makes it successful.

The first is that innovation belongs to the realm of uncertainty. Every business person knows what risk is. Every business venture includes a risk of failure and a probability of success, and these are more-or-less measurable entities. Innovation, on the other hand, deals with uncertainty. At the outset of an R. & D. project, there's no way to predict what you'll find, when you'll find it, or how successful it will be. That's uncertainty, and it's an especially uncomfortable feeling in the no-nonsense world of the bottom line.

Second, innovation depends on patience. In the industrial world, 10 years is considered about average time for bringing an R. & D. project from idea to commercialization. This means that successful innovation demands long-term commitment. But this long-term outlook may conflict with the one-year budgeting cycles of most businesses. Thus, innovation demands a great deal of patience from the sponsor of the R. & D. project.

Third, successful innovation occurs only with proper timing. Commercializing a research project is like aiming at a moving target. No matter how good the product, the investment has been wasted if the public isn't ready to accept it. The convergence of public readiness and scientific readiness opens the window to innovative developments.

Bearing these three axioms in mind, I'd like to discuss briefly a long-term biomedical research project being conducted jointly by Harvard Medical School and Monsanto. To my knowledge the program is unique. My purpose in discussing it here is not to suggest that this arrangement will work for everyone. Rather, I want to demonstrate that it is possible to benefit the entity that does the basic research, the entity that takes the entrepreneurial risks, and the consuming public—all at the same time.

There are five basic concepts that make up and hold together the Harvard-Monsanto agreement. Let me review them quickly.

The first is that Monsanto set out to create for itself a "window on biology." Biological chemistry is becoming increasingly important to our business, yet this is not among the traditional areas of our expertise. Thus, we went looking for a few superlative researchers in this field with whom we could work comfortably. We happened to find them at the Harvard Medical School.

The second concept involves inputs to the joint arrrangement and what each party hopes to get out of it. Monsant provides money and technology while Harvard

performs basic research involving the molecular basis of organ and tissue development. The research scientists are free to publish their findings while Monsanto can commercialize useful products growing out the research.

Third, our agreement regarding commercialization is based on the Institutional Patent Agreements issued through the Department of Health, Education and Welfare. Monsanto receives exclusive license to commercialize. Harvard receives support for its research and royalties for its patents, as well as "march-in" rights should Monsanto fail to commercialize a discovery within a specified time period.

The fourth concept involves built-in guarantees of a long-term commitment to the project from both sides. The agreement runs for 12 years, and we're about midway now. Termination was not allowed for the first four years, and even now would require advance notice. This recognizes that you can't expect innovation to flower if you keep yanking it up to check the roots.

Fifth, recognizing the uniqueness of this joint project and the considerable public stake in the outcome, Harvard and Monsanto agreed to create a public advisory board. Five people, having no formal connection with either institution, we selected for their ability to represent the public interest in this venture. They are regularly kept informed as to the state of the research. * * * will be worthwhile legislation. To this end, let me offer four specific recommendations that I believe will help this bill accomplish its purposes.

First, I believe the success of the Centers for Industrial Technology absolutely depends on granting exclusive license for commercialization of patents. Government-held patents today are licensed largely on a nonexclusive basis. As a result, only about 4 percent of such patents have ever been successful commericalized. Without promise of exclusivity—with appropriate "march-in" rights, of course—few companies are willing to invest the time, talent and money it takes to carry a basic discovery on to applied research and commercialization.

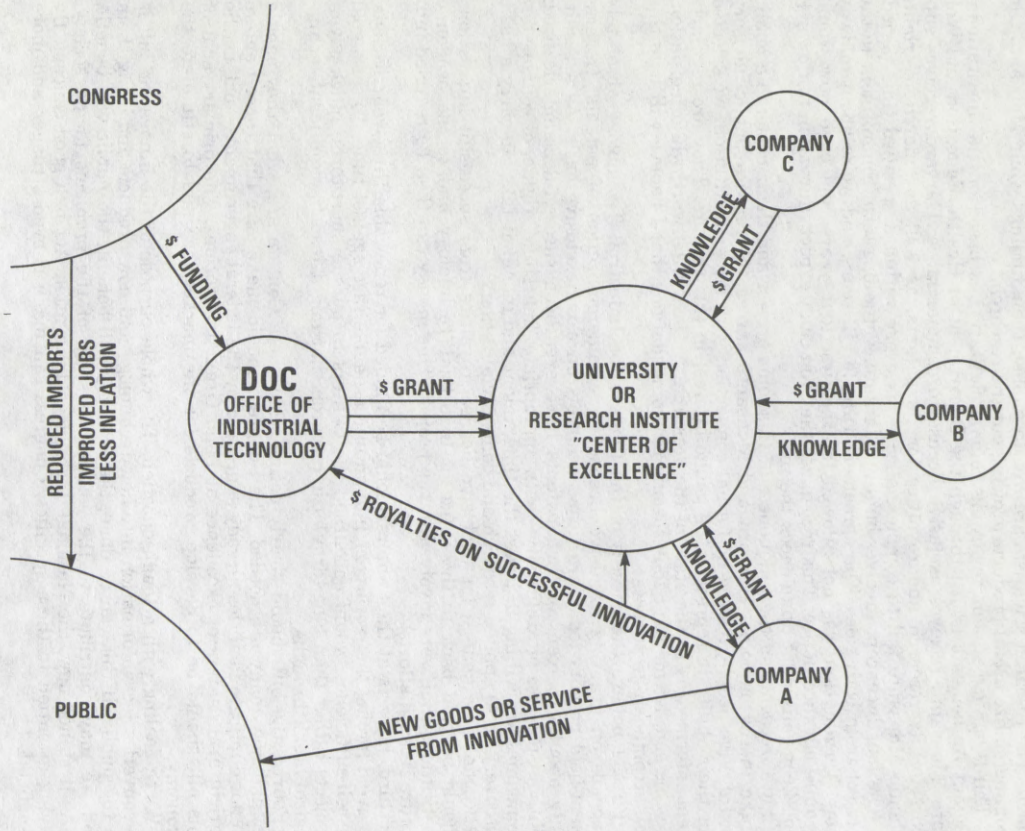
Second, in exchange for exclusive license, royalties from successful innovations should be paid back to the Office of Industrial Technology and to the academic institutions that were involved in the project. This money can then be recycled into future reseach efforts.

Third, projects at the Centers should be funded for renewable three-year periods, to avoid forcing the researcher into an unreasonable race against time. To set a goal of self-sufficiency would encourage the Centers to pursue short-term, quick-payoff projects rather than long-term basic research that might lead to significant technological breakthroughs.

Fourth, the bill should clearly define what these Centers are, what they should do, and how many are needed. The Congress should make sure that these Centers do not duplicate facilities already supported by the federal government—such as the agricultural centers of excellence at Land Grant institutions. The primary goal of this bill should be to develop products for the marketplace and to stimulate the economy.

We're dealing with a tough question. The whole purpose of the innovation bill is to convert select information into new technology and new products and bring them to the public. If this can be done, the economy will benefit, the public will benefit, and we may contribute to the solution of some of the problems facing society.

As it stands now, the National Technology Innovation Act is a good concept. By paying attention to these specifics, Congress can make it even stronger and more beneficial.


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STATEMENT OF MONTE C. THRODAHL, SENIOR VICE PRESIDENT, MONSANTO CO.

Far more doctoral scientists are engaged in research for academia than for industry, yet only a trickle of the university-innovated technology is reaching the public. Moreover, within industry, a given company has access to only a limited number of scientists to do innovative research.

The proposed National Technology Innovation Act of 1979 can be an important first step in broadening avenues of communication and collaboration between these academic and industrial scientists. Thus, it could also be a major step toward revitalizing the whole innovation process in the United States. I applaud this effort by your committee, and offer my full support. I believe that industry, academia and government working together can provide a solid base for our innovative future.

Just as there is inherent strength in any triangular structure, there is great potential in a shared effort by these three major influences on the public sector: our government, our centers of learning and our businesses. I would like to present in general terms an industrialist's view of the complex business of innovative research and the need for industry-academic-governmental cooperation in this vital field. Specifically, I will draw from the experience of my own company, in traditional relationships with academia, and also our joint research project with the Harvard Medical School to illustrate what I feel are pluses and problems in such relationships. Then, briefly, I will mention individual points in the bill which I believe are deserving of comment.

Skills and knowledge are key ingredients to successful innovation, but they are not enough to guarantee success. Innovation comes out of the realm of uncertainty: no one can predict how or when a promising innovation will occur. Often, innovation depends on serendipity—a happy accident of skills and knowledge and timing and ideas which come together to produce results not predictable ahead of time. This is true whether the research is undertaken in business, in academia or in government.

However, in dealing with innovation—as a business manager, a lawmaker, or a researcher—there are three axioms which are worth bearing in mind.

First, innovation is uncertain. Every business venture contains risk of failure, but generally also has a known probability of success. The broader uncertainty of R&D, which cannot be predicted with accuracy, is hard to live with, especially in the no-nonsense world of the bottom line.

Second, innovation depends on patience. It cannot be programmed; it cannot be ordered up to meet certain requirements by a certain time. Patience is not a commodity item in the business world.

Finally, innovation occurs only with the proper timing. Commercialization of a research project is like aiming at a moving target: no matter how good the product, the investment has been wasted if the public isn't ready to accept it. The convergence of public readiness, and scientific readiness opens the window to innovative developments.

It is for these reasons that the innovation picture should be of concern to the public sector as well as to entrepreneurs. And it is also for these reasons that joint relationship are worth seeking out. By bringing industry more closely into the picture for government-funded academic research, the general research capability of the universities will be enhanced.

Moreover, the taxpayers' dollars will go further, because of the additional financial input by industry into academic research.

Most important, however, is the fact that involvement of private companies in a research program increases the probability that it will ultimately result in a product that will benefit the consumer.

This essentially, is the underlying philosophy upon which Monsanto's unique research joint venture with Harvard Medical School is based.

For years, Monsanto has maintained ties with academia. Initially, our relationships were rather traditional in nature, dealing only in areas not already supported by government funding. More recently, however, as our needs changed, so did our method of interacting with academic research people. We began to want more from the academic relationships, and we began to believe that academia should be able to get more in return. Let me explain.

Over the years, Monsanto has taken part basically in three conventional types of associations with academia: industrial affiliates programs, broad sponsorships and specific collaboration.

Industrial affiliates programs such as those which Monsanto has participated in with MIT, California Institute of Technology and Stanford, are all similar. Businesses which become members of the affiliate groups, receive special publications, attend seminars and have access to certain information from the sponsoring university.

Broad sponsorship covers a spectrum of programs, from blanket grants for research, to scholarships such as Monsanto's $500,000 in Toxicology Fellowships for training of graduate toxicologists. The results are usually that Monsanto participates in the accumulation of knowledge in a given area. Rarely do we expect our donations to produce products or profits for us.

The third form of interaction between Monsanto and academia occurs in cases of specific collaboration. These relationships include such things as employing university professors as consultants, organizing seminars and contracting research groups in universities to run tests or carry out other specific work for us. In all three areas, conversion of scientific data into products, processes or materials for consumers has been limited. But we did not expect more.

In very recent years, however, the picture has changed. There has been a trend away from basic research within industry, and a corresponding trend in government to reduce the funding of academic research. The loss is not felt by academia or industry along though, but by the people as well as—in terms of higher prices, slowing economy and fewer jobs.

However, those trends contributed to the formation of Monsanto's present collaborative agreement with Harvard Medical School. To my knowledge, the program is unique. I believe it exemplifies the best possible kind of industry-academic interface possible, up to this time. The idea for such an association developed as Monsanto discovered that our traditional expertise in chemistry and physics would not be enough to carry the company into the 1980's. To meet the challenge of the future, Monsanto needed a more complete understanding of mammalian biology. To gain this understanding, Monsanto chose to go to academia—where most of this type of research still takes place. With the Harvard relationship plus other associations with other institutions, we have created for ourselves a Window on Biology. But we wanted more than general knowledge. We had a specific goal in mind.

In simple terms, the agreement which was eventually worked out with Harvard is that Monsanto provides money and technology for Harvard's fundamental research. The University scientists are free to publish findings and Monsanto can commercialize useful products growing out of the research.

Our agreement regarding commercialization is based on the precedent set out by Institutional Patent Agreements issued through the Department of Health, Education and Welfare.

Monsanto receives an exclusive license to all Harvard inventions under the project agreement, subject to government policies and rights, since government funding was involved in early stages of this research. If Monsanto has not commercialized after a period of exclusivity, then Harvard has "march in" rights. Harvard receives royalties from its own patents. An extra feature is that Harvard also receives royalties from Monsanto patents which resulted from significant Harvard input.

Whether or not the research culminates in commercial success, this is an expensive undertaking for Monsanto, not one which we could afford to enter hastily, and not one which we could afford to readily duplicate. Nor is it one which we can terminate easily. Monsanto is committeed to the joint research project with Harvard for 12 years. Termination was not allowed during the first four years; it is only possible now with advance notice. This time frame is important to the possible outcome of the research. In the chemical and biological sciences especially, time is a key component to innovation, as I mentioned earlier. Research projects, like growing plants, must be nurtured with care and patience. Even though periodic reviews are imperative, funding and staffing support must be guaranteed for the long term. It serves no useful purpose to yank a plant out of the ground by the roots to check on its progress. Similarly, innovative research must be allowed to take its course, sometimes over many years. This is not always easy.

Within the business sector, and also among custodians of federal grant monies, there is a growing demand for quick payoffs from investments, even R&D investments. Budgets are organized on a year-to-year basis, and more and more, R & D is being called on to produce year-to-year results. Unfortunately, one year is rarely long enough to know if a project is worth pursuing, much less if it will produce commercial successes. Within major industries, it is acknowledged that a reasonable time frame for innovation is 10 years.

Thus the 12-year time frame for our Harvard agreement was arrived at after much deliberation, and is a key part of the joint arrangement.

Another major provision in our basic agreement has arisen out of an understanding that the public also has a stake in the work. Because we recognized that biology is so intimately related to the problems of food, population and health, we became concerned about how our activities in this venture will affect the public interest. As a result, the Harvard/Monsanto agreement also provides for a public advisory board. None of these five people has any formal connection with either the universi-

ty or the corporation. The Board members were selected for their ability to represent the public in this venture, and are kept informed as to the state of the research.

When Monsanto decided to pursue this venture, we were interested in something more than a traditional relationship. We had to find a university which was willing to gamble, just as we were, that the outcome would justify the risks taken. These are the kind of risks that flaunt tradition, public expectation, and to a certain extent, they flaunt institutional philosophy. To reach an agreement the university had to change its patent policy. We had to be willing to give up some of our trade secret status on a project, and be willing to allow timely publication of research results, even should this result in loss of patent protection. While we were straining our traditional business security for the Harvard requirements in the Harvard Project, we were encouraging the University to think in financial as well as philosophical terms. To university scientists our message is that the rewards of academia are broader than publication of papers. To the Universities, we extend the idea that they should be reimbursed for the results of their professors' research.

The Harvard/Monsanto agreement is not perfect. But we feel we did the best job we possibly could under the existing constraints of law and tradition. The proposed act takes into consideration many of the issues which we faced in pursuing our Harvard Agreement, with positive results.

I would now like to make some specific comments on the draft bill, as it relates to Monsanto's experience in working closely with Harvard and other academic institutions.

Specific suggestions and comment: Monsanto feels that the following sections must be changed in order to safeguard the integrity of this Bill:

Page 6, line 12: Sec. 6(a)(2)—This point is important, especially for fragmented industries which may not have the funds or the inclination to invest heavily in R&D which will not provide an exceptional, large return on investment. Where several companies in same industry fund a Center, there are possible antitrust complications. Wording should be added to deal with this.

Page 6, line 17: Sec. 6(a)(3)—Work in these Centers should be directed toward subjects which bridge between basic research in Universities and development of products or processes in companies. There are other federal agencies with a mandate to support research on regulations. This section should be omitted.

Page 7, line 17: Sec. 6(b)(4)—Basic training for the role of innovator is already provided in the normal education process. The cooperative program will automatically provide further training by providing increased interaction between academic and industrial scientists. Thus, the former will learn more about how the latter think and act. This section should be omitted.

Page 8, line 6: Sec. 6(c)(3)—Short-term quick payoff projects will provide financial security and self-sufficiency to a Center, where long-term, more risky ventures will eventually have a more profound social and economic significance. Since the intent of the bill is to encourage major innovations the portion of the statement relating to self-sufficiency should be omitted.

On page 9, line 8: Sec. 6(e)(3)—Licensing should be on an exclusive basis, except in rare circumstances. Otherwise, industry does not have incentive to make the initial investment. Universities should be able to grant licenses as they choose, dependent only on the contract between industry and university. Except in very special circumstances, nonexclusive licensing has not led to commercialization.

Page 9, line 12: Sec. 6(e)(4)—Monsanto supports the idea of "march in" rights for the university, in order to assure that continuous effort be made to pursue commercialization of innovations. The period of exclusivity should be agreed between university and industry, and certainly must allow for recoupment of investment as provided in the bill.

Page 9, line 16: Sec. 6(e)(5)—Universities should realize financial gain from fruits of their research efforts, as well as prestige of Sec. 6(e)(4). Monsanto supports the idea of "march in" rights for the university, in order to assure that continuous publication. We support this section. In addition, a percent of the royalty payment should also be earmarked for the government. Because the government shares in the risk of financing the innovation, it should also share in the rewards. In this way, the exclusive license is not a giveaway. The royalty payment could then go back into the Office to supplement the annual appropriation and thus increase the amount of funds available for grants.

Page 10, line 7: Sec. 7(a)—Cooperative funding will be a boon to small businesses that wish to engage in major research, and also to fragmented industries where the cost of the project may be more than the potential return to an individual company. However, large companies such as my own could be encouraged with a lower percentage of funding support. I suggest that the committee set levels of govern-

ment contribution depending on the size of the company. One plan might be to fund up to 75% of a project for companies with sales up to $10 million per year, and fund 50% of projects for companies with sales greater than $10 million. Not only would this benefit smaller businesses, it would cause larger companies to consider more carefully before becoming committed on a joint undertaking with academic researchers—to verify the validity of the project.

Page 10, line 13: Sec. 7(b)—Six months is too long to wait for notice of acceptance for a grant proposal. This time should be limited to three months. Some wording should be included in this section or elsewhere regarding the length of time the grants are to cover. Three years would be a preferable minimum time frame, in terms of R&D outcome, to one year. R&D projects require momentum, generally far longer than 12 months. However, provision should be made for periodic reviews and cancellation should lack of progress be apparent.

Page 11, line 3: Sec. 7(c)(2)—This section is too restrictive. It should be left to the discretion of the funding officer to determine whether the plan for using money is appropriate or not, without restrictions on types of expenses.

Page 11, line 7: Sec. 7(c)(3)—This section should be expanded to require a regular periodic audit of the research projects to assure that projects are being carried forward and progress is being made.

Page 13, line 5: Sec. 9(b)—The Director should recommend and the outside panel should make the final decision on establishing the Centers for Industrial Technology. The panel members bring a more varied perspective to bear on the proposals and stand to have a better understanding of what kind of Centers are actually needed. This, of course, would require that the panel hold regular meetings.

Page 15, line 4: Sec. 10(a)—Available funds should become incrementally larger than proposed here, to take into account the effects of inflation and the need for long-term funding of projects. We would recommend 1980 $25 million, 1981 $50 million, 1982 $80 million, 1983 $85 million, 1984 $90 million.

Page 15, line 10: Sec. 10(b)—The budget should be renewable annually. Moreover, a $10 million budget presupposes a staff of 100 people; $3 million would be a more reasonable budget to carry out the provisions of this Act.

Senator STEVENSON. Dr. Mead.

Dr. MEAD. I would like to give the chairman and the committee some perspectives about the electronics business, which is the business with which I am principally concerned. More particularly, the semiconductor business, which has been widely touted as an example of the fastest innovation rate of any industry. I would like to share with the committee some of my perceptions as to why that industry has evolved so rapidly.

My points of view are really from four different kinds of involvement with the business: First, a basic research at the university and an educational program at the university, including joint programs with large industrial firms.

My second involvement has been as a consultant to large industrial firms in the business—quite a number of them.

I have also participated in the founding of half a dozen new ventures in the electronics business, and I have acted as a consultant to venture capital firms that were looking for firms in which to invest.

The first observation I would make about the business is that while many of the basic ideas which later became incorporated in products—the fundamental ideas came from universities and from industrial laboratories and on occasion Government laboratories—the thing which really caused the innovation to happen was the introduction of these ideas to the marketplace. And that was done almost universally by new ventues.

I think the reason is that once a company gets into a marketplace, has defined its role in the marketplace and is fighting for a market share, it simply is not possible to get the attention of the top executives in those firms focused on embryonic opportunities,

because those embryonic ventures do not generate enough revenue to compete with the large-volume business decisions that are the main bread and butter of the company.

I think there's nothing about large firms that makes them evil or sinister in this regard. It's just that they are pursuing, maintaining themselves firmly in their mainstream of business. They simply can't be watching all the opportunities that come out of R. & D. labs, or the ideas that the engineers have, or the new things happening in the universities.

In the semiconductor business there was wave after wave of new ventures that started from ideas that actually came from the large semiconductor companies that had found a place in the marketplace, and there were opportunities generated by the research and the development in those firms which were not capitalized on by those firms, but by spin-outs of one sort or another. A few engineers would get some venture capital and go off and start another company. That has become a way of life out in what we call "Silicon Gulch"—the San Francisco peninsula in California. It's also happened in many other places in the country.

I think the mechanism for that leads us to watch what might happen in the future in this business, and the outlook is not very good. As you know, we have been losing ground in that business to the Japanese, and the Europeans are coming on strong. I have tried to understand why that is, and I think I can present a plausible argument for why it is we are losing ground there and what can be done about it. This legislation could address these issues directly with only a slight modification.

What has happened recently in the semiconductor business is the fabrication technology has been so well developed that it is possible to build very large systems on one tiny piece of silicon. For that reason, the thing which is limiting the industry is not the ability to replicate these patterns, to actual fabricate the chips which go into your watches or calculators, or whatever, but the ability to design such things in the first place.

The way design innovation is done is a lot of people—a very large number of people—have a try at it; some of them will come up with good designs and others won't. There simply needs to be more design innovation than can be done within the large semiconductor and computer companies that are operating today.

We have been working very hard to get an educational program in the design of these very large scale integrated systems. There are enormously exciting possibilities here. We are working with about 15 other universities, trying to help them start courses in this subject. There has been a lot of interaction with industry along the way, and that's all going very well.

There is a problem. There haven't been any spin-outs and new ventures in that business for a long time, and the reason is very clear. The fabrication technology has become so demanding that it now requires of the order of $20 million to make a fabrication facility. It used to be, when you started a semiconductor company it would take $1 million and you could put up your own fabrication facility and start designing parts and shipping them. It's been a long time since the last one of those, because the $20 million is

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simply beyond the venture capital resources that you have access to when you go to start a new venture.

What is needed here is a new kind of support business which can service the universities and the small business community so we will see some new ventures based on design innovation.

That kind of facility would be a central resource which could act to take in the designs that people have done, replicate them on silicon, and give back the replicated parts.

The fabrication of integrated circuits on silicon is analogous to a printing operation. Very sophisticated, but in fact it's just a replication operation, like printing books. The situation today is very much like it would be if the only people who could write books had to work for companies that ran a big printing operation. You wouldn't get nearly the variety of literature that you get when people can simply act as authors and then go to someone and have books printed.

What we're really talking about here is a kind of freedom of the press for the silicon business—people being able to get their designs replicated without having to go out and scare up the capital and put up one of these giant facilities for doing a replication.

I have three specific suggestions for the legislation:

The first one is to recognize in the findings the key roles that have been played by new ventures in innovation in this business, which I think serves as a role model for how a lot of innovation can be done.

The second is to expand the notion of the centers just slightly to include not only doing the basic research and development but also the possibility that one might serve to act to supply an essential service, such as the one I have been talking about, to the university and small business community.

I think the third one is addressed to the mechanism of making the center self-supporting. If a center were established to set up a service facility such as I'm proposing to provide fabrication service to the evolving innovators in system design—small businesses and university departments which are doing that—the facility could very rapidly become a moneymaking business. I would suggest a general mechanism for making centers self-supporting to allow them to spin out new ventures as profitmaking businesses and let the centers taken an equity position in these ventures.

The role of the Government in this case could be a sort of pump-priming operation.

Until a facility such as I have described exists, people simply won't start new ventures to make use of it. Once it exists, it will be patronized by the university and small business communities. It can become profitmaking, and that is the way it can be spun out into business.

Those are my three suggestions.

[The statement follows:]

## Statement of Carver A. Mead

## VLSI AND TECHNOLOGICAL INNOVATION

Rather than innovation in general, I will discuss what I believe to be the most important opportunity since the industrial revolution, rivaling it in significance. This unique circumstance is created by the emerging Very Large Scale Integrated (VLSI) technology, with which enormously complex digital electronic systems can be fabricated on a single chip of Silicon one-tenth the size of a postage stamp. Out of it systems will be created which radically change our modes of communication, commerce, education, entertainment, science, and the underlying rate of cultural evolution. The quality of human life can be improved in remarkable ways by these changes. Electronics creates no noxious by-products and uses only miniscule amounts of energy. It can accomplish tasks which were previously energy intensive, and dangerous or degrading to human workers. There is no doubt that this electronic revolution will take place. The question is whether it will flourish in the free world, and in particular whether the U.S. will be able to recover the commanding lead it has recently been losing to foreign competitors

For 20 years the U.S. semiconductor industry has been the world's prime example of innovative excellence. Each new round of technology was carried by a new wave of start-up companies financed with venture capital. These in turn became the mainstays of their market, only to spawn another brood as a new opportunity unfolded. Each turn of this wheel of fortune added new markets, formed new capital, and created additional jobs. The spirit of those heady times is by no means dead, but the basic nature of the game has changed. System design, not technology, is now the arena in which small firms outshine their giant mentors. Implementation of such designs, however, requires a silicon wafer-fabrication capability unaffordable by any single small-enterprise. A fabrication facility serving many such firms can set the industry on a course even more exciting than that of earlier times. In what follows I have tried to describe the status of the field and how a simple, decisive act can assure a dynamic new round of innovation within it.

### Innovation

I have found the following simple view helpful in understanding how innovation has worked in the past, and how we might encourage it in the future. The semiconductor technology is composed of a set of disciplines which must be considered separately. In any given discipline, innovation proceeds along an S shaped curve such as that shown in Figure 1. In the early phases, marked (A) in the figure, progress is limited by the lack of fundamental ideas. A single good idea can make possible several other good ideas and hence the innovation rate is exponential. During this period, a single individual or small group of individuals can develop a viewpoint and contribute several crucial insights that set a field in an entirely new direction. It is the time during which progress is dependent upon a few visonaries within the field. During the central and most visible portion of the evolution, marked (B) on Figure 1, a linear region ensues. Here, the fundamental ideas are in place and innovation concerns itself with filling in the interstices between these ideas. Commercial exploitation abounds during this period. Specific designs, market applications, manufacturing methods grow rapidly. The field has not yet settled down at this point. Entrepreneurs backed by venture capital firms can have a large impact and achieve a dominant market share during this period. During the later stages of the evolution curve, marked (C) in Figure 1, progress becomes logarithmic in time. Few changes in the market share "pecking order" occur. Manufacturing methods are refined ever further. More and more capital is expended to reduce the price of manufacturing. Here, the business becomes capital intensive. Production know-how and financial expertise are the required credentials. Professional managers and large firms dominate the business.

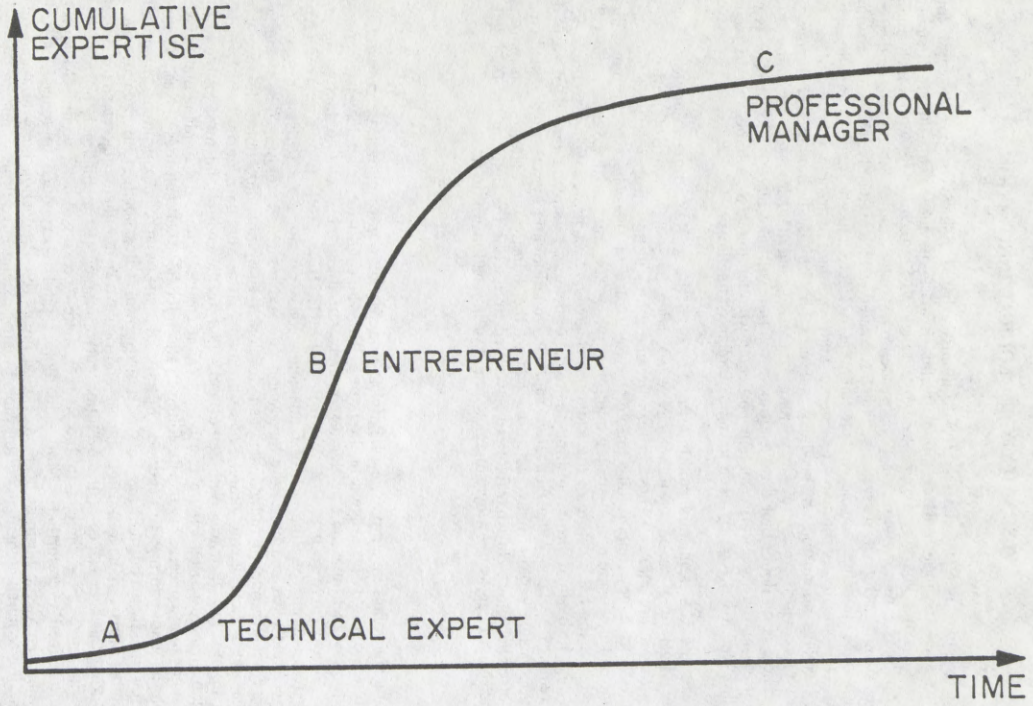



Fig. 1 The Evolution of a Dicipline

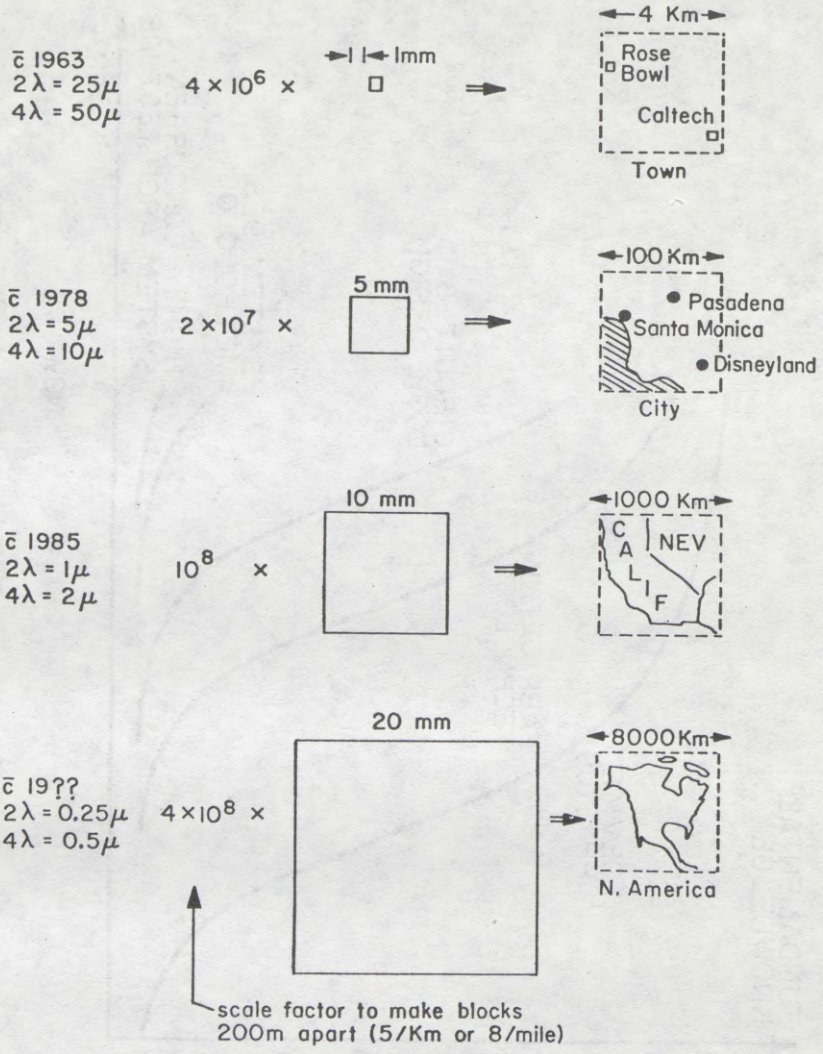



Fig. 2 VLSI Complexity Analogy

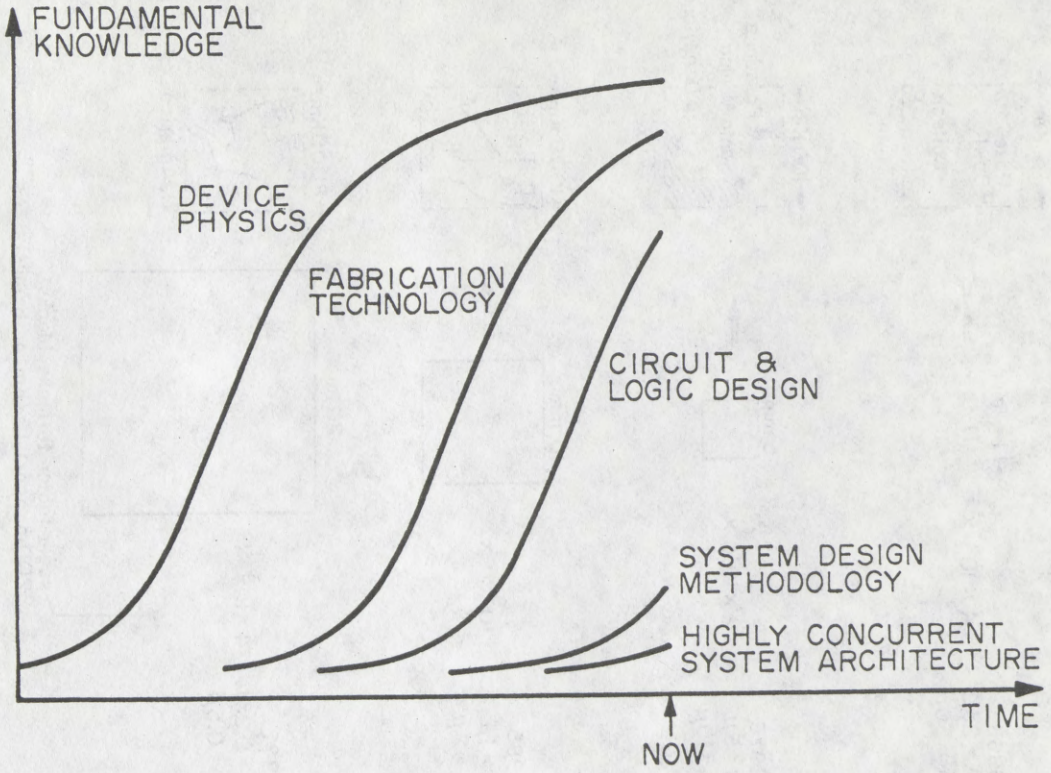



Fig. 3 Component Diciplines of the VLSI Culture

**The Arena**

VLSI is a statement about system complexity, not about transistor size or circuit performance. VLSI defines a technology capable of creating systems so complicated that coping with the raw complexity overwhelms all other difficulties. From this definition, we can see that the way in which the industry responds to VLSI must, in fact, be different from the way it has historically evolved through its other phases.

The complexity scale implied by the new technology can be appreciated from the analogy[1] presented in Figure 2 . At several points in the evolution of the technology, a typical chip has been scaled up to make the spacing between conductors equal to one city block. The circuit can then be thought of as a multi-level road network carrying electrical signals instead of cars. In the mid 1960's, the complexity of a chip was comparable to that of the street network of a small town. Most people can navigate such a network by memory without difficulty. Today's microprocessor using a $5\mu$ technology is comparable to the entire Los Angeles basin. By the time a $1\mu$ technology is solidly in place, designing a chip will be comparable to planning a street network covering all of California and Nevada at urban densities. The ultimate $1/4\mu$ technology will likely be capable of producing chips with the complexity of an urban network covering the entire North American Continent. Designers are just now beginning to face complexity as a central and dominant issue of the next stage of evolution. In order to realize the full potential implied by such complexity, entirely new design methods and system organizations must be invented. A high rate of innovation is required to achieve leadership in this remarkable arena.

The evolution of the component fields which make up the present VLSI discipline are shown schematically in Figure 3. Progress in each depends upon those before it being well in place. By now, the number of dramatically new ideas being added to the device physics area is small. Fabrication technology has essentially all the fundamental knowledge that will be required. Circuit and logic design have some cleverness left but that too will soon saturate. The large system design methodology is still in its exponential phase. Many fundamental ideas have yet to be discovered. The organization and programming of highly concurrent systems are even less well developed. Only a few results are known and much of the fundamental conceptual apparatus needs to be discovered. A period of very rapid growth lies ahead of us in both of these disciplines. They are central to the difference between VLSI and the current way semiconductor devices are designed. It is here that the major innovative possibilities lie.

Historically, innovation in the industry has been spearheaded by small start-up firms and later taken up by large existing organizations. It is significant that the major suppliers of vacuum tubes did not become the major suppliers of transistors. The major suppliers of discrete transistors did not give us semiconductor memories. More recently, companies dominant in the semiconductor memory business did not bring us the multiplexed address random access memory. The microprocessor did not come from mainframe or minicomputer firms. Each of these innovations was brought to market fruition by a small start-up firm which rapidly gained market share by virtue of its innovation. Existing dominant firms were then forced to retrofit these ideas into their own product lines. For the reasons mentioned above, I expect this trend to be even more apparent as VLSI evolves.

The problem faced by the semiconductor industry is thus apparent. Fabrication technology has reached its capital intensive phase. Design is still very early in its exponential phase. Each small system group can no longer afford its own fabrication area. A start-up firm of ten years ago with a capital budget of one or two million dollars for a fabrication area was within the means of traditional venture capital sources. However, the same is not true for capital budgets of several tens of millions of dollars required for state-of-the-art fabrication lines in the near future. If innovation by a myriad of small groups and individuals is to carry us into the VLSI revolution, we must not expect these groups and individuals to provide their own fabrication facilities. The level of innovation required can be achieved only if fabrication is provided as a service by a few well capitalized firms.

Every time a qualitatively new element has been introduced into the industry, new business opportunities have been created. Small firms have obtained significant market shares by extending markets previously dominated by larger firms. The VLSI revolution we are facing is no exception. I fully expect a very large number of small firms to create entirely new machine organizations and entirely new design methodologies. These will allow small, able groups to succeed in the varied market place for systems in spite of historic dominance by capital intensive computer and semiconductor houses.

The seeds of the new wave of innovation have already began to take root. Much of the thrust is coming, not from the integrated circuit industry itself, but from the collaborative effort of faculty members in many university computer science departments and scattered individuals throughout the industry. The university community includes Caltech, M.I.T., Carnegie-Mellon Univ., U.C. Berkeley, Univ. of Utah, Washington Univ. (St.Louis), and Univ. of Florida More recent collaborations include Stanford, U.S.C., U.C.L.A., and the Univ. of Washington.

A new type of course is being offered at these schools that provides students of computer science and electrical engineering with a thorough introduction to integrated system architecture and design. The courses provide the minimum of basic information about devices, circuits, fabrication technology, logic design techniques, and system architecture, which is sufficient to enable the student to span fully the entire range of abstractions, from the underlying physics to complete VLSI digital computer systems. Only a surprisingly small set of carefully selected key concepts is necessary for this purpose. By minimizing the mental baggage carried along at each step, the students emerge with a good overall understanding of the subject. The courses are based on a course I originated at Caltech in 1971, and on a new and highly simplified integrated system design methodology that Lynn Conway (of the Xerox Palo Alto Research Center) and I present in a major new textbook on the subject[2].

A major portion of these courses is devoted to "learning by doing", with the students undertaking the architecture, design, layout, and testing of substantial LSI system projects. A typical student project might contain on the order of several hundred to several thousand transistors. The students typically describe their designs using a symbolic layout language. Only modest facilities are needed to support such courses, in addition to that commonly available at these schools. The schools do not usually have their own LSI fabrication facilities. The "multiproject chips" containing all the LSI projects for such a course are instead fabricated by commercial maskmaking and wafer fabrication firms, directly from the design files produced by the students.

Throughout the evolution of courses and research projects, we have constantly been hampered by the difficulty of gaining access to wafer fabrication service. Although many industrial firms have been very helpful in this regard, their facilities are dedicated to their own proprietary products, and were made available to us on a special case, special favor basis. While these favors were crucial to getting the university programs going, they obviously cannot be the basis for supplying a multitude of emerging small system firms, nor can they effectively support the expanding group of participating universities. What is needed is an openly available service facility which will, for a fee, accept pattern files in a standard format (which we have already worked out) and "print" them on silicon wafers using a standard fabrication process.

The analogy with printing is a particularly apt one.[3] While wafer fabrication is the most sophisticated manufacturing technology ever undertaken by the human race, it is *pattern independent*. A limitless number of system designs can be replicated by a single process, much as books on any number of subjects can be replicated by a single printing press. Individual designers require access to fabrication in exactly the same way that individual authors require access to printing.

An open fabrication service should be established as the collaboration of an industrial partner with the university community. The role of Government in this venture should be that of "priming the pump". Funding arrangements should be left flexible, and a rigid format should not be prescribed. Once one or two of such facilities have been operating for a year or two, demand will increase and they should become profitable business enterprises in their own right. It is important that the only restriction placed by the Government on these facilities is that they make fabrication service openly and uniformly available. In all other respects they should be treated as independent, unregulated corporations. Several commercial firms and groups of individuals in the industry have already indicated an interest in operating such facilities. Whatever other goals are addressed by the pending legislation, this opportunity must not be allowed to slip by. It is perhaps the only way to assure Freedom of the "Silicon Press".[3]

REFERENCES

(1): Charles Seitz, "Self-Timed VLSI Systems", from the *Proceedings of Caltech Conference on VLSI*, January, 1979.

(2): Carver Mead and Lynn Conway, *Introduction to VLSI Systems*, limited printing by the authors, 1978; Addison-Wesley, 1979 (in press).

(3): Lynn Conway, private communications.

Senator STEVENSON. Thank you, sir. Would any of you like to comment on the comments of others before we weigh in?

Dr. HOLLOMON. I've only one comment to make, and that is to reemphasize the importance of the small firm—the growing new venture—as a predominant job-creating device for this country. The general trend of a mature business, even in a growing business, is to improve its productivity.

The evidence now is clear that small firms growing in new areas create jobs much more rapidly than large firms.

Senator STEVENSON. Will that be true even in the future, when you consider the magnitude of the finances involved for research?

Dr. HOLLOMON. I don't know of any evidence that the situation will change in the future. Let me put it this way: I believe that the situation that's just been described, which is a large firm in a mature business, has to tend to its knitting, has to gradually improve its product and improve its productivity and will devote itself so intently to that, that new ventures must be specially supported to stimulate the new.

Much of the research and development will be done in large organizations. But on the other hand, the new business must develop outside the large firm.

Senator STEVENSON. Hasn't Bell Laboratories been interested in innovation?

Dr. HOLLOMON. Has what?

Senator STEVENSON. Hasn't Bell Laboratories been the source of innovation in business?

Dr. HOLLOMON. Large laboratories like Bell and one with which I was associated 15 years—the GE Research Laboratory—have been the source of many ideas. As a matter of fact, even with the transistor, its exploitation occurred outside of Bell and outside of the Bell System by firms that did not exist before, or firms that were entirely different businesses.

Established firms are seldom the exploiters of the radically new—are seldom the exploiters of the radically new.

Senator STEVENSON. Would you feel better about Bell Laboratories if the Justice Department succeeds?

Dr. HOLLOMON. I don't intend to argue that because small entrepreneurial firms are crucial, that that automatically argues that Bell Laboratories isn't important.

Senator STEVENSON. I think you're suggesting we need them both.

Mr. Throdahl?

Mr. THRODAHL. I think I would like to offer a very small point. I do agree basically that once you've got the eggs in the basket, you've got to watch the basket. But certainly in fields that are fast evolving—and I happen to have spent my career in one—we have been and have got to accelerate doing things for tomorrow that we don't know how to do today.

We just know that we've got to look for new pastures.

Now, maybe we'll run out of those ideas, but I guess I have a hard time to stay that it's got to be one way or the other, and I'm only pleading for a slight modification. It's got to be balanced a bit.

Senator STEVENSON. Dr. Mead, I think you're next.

Dr. MEAD. Yes. I would like to comment about that—about the large firms in the semiconductor——

Senator SCHMITT. Mr. Chairman, could I check Dr. Mead's credibility and ask him which house he was in at Caltech in 1956?

Dr. MEAD. I was in Blacker.

Senator SCHMITT. That's what I thought. I thought I recognized your face. That's an acceptable credibility. I was in Dabney. We won't go into the various expressions applied to Dabney.

Dr. MEAD. In the semiconductor business, one of the trends that has become very clear is that a new firm will take an idea, concentrate on that idea, bring it to the marketplace, and prove it in the marketplace, and show it's successful. Once that happens, many of the existing firms will adopt it, retrofit it back into their product lines and become competitive in the new market.

So, in fact, there are two mechanisms by which large firms can benefit from innovation by new ventures. One is by this mechanism of competitive pressure to get it into their product line. The other is by acquisition. Many entrepreneurs now find that's the way they can recover their investment in the new ventures, to get acquired by somebody and then that whole thing gets incorporated in a larger product line. In fact, that's good for everyone. I didn't mean to imply that larger firms don't end up with innovative things. But they very often pick them up from other folk.

Incidentally, you talk about Bell Labs. Bell Labs often picks up ideas from folk around universities and in other businesses and then does a better job on them. So you will see that a lot of those things didn't actually originate there; they originated someplace else, but they have the manpower to do a good job.

Senator STEVENSON. Dr. Goldman.

Dr. GOLDMAN. Apropos the same subject, I think it's important that we keep in mind the distinction between invention and innovation. This was talked about a little earlier. Innovation, in the final analysis, often depends—not always, but often—depends on the existence of inventions, and the large corporations, particularly

those that have high-level intensive research and development organizations, are a center for invention.

And, I think, to again seize your example, Mr. Chairman, of Bell Laboratories, a very significant number of major inventions over the years have come from Bell. They were translated into innovations to a large extent by other companies in the semiconductor business, now in the magnetic bubble business.

Conversely, they picked up the solid-state maser which was invented at Harvard and were able to bring it out very rapidly for particular applications for which they saw a need in communications.

I would like to talk to another aspect that has come up this morning, Mr. Chairman. Professor Mead made reference to Silicon Gulch, and many regions around the United States—municipalities, State governments, agglomerated areas—have been so very much interested in how does one attempt to emulate Route 128 and Silicon Valley, in order to give themselves an innovative and economically vibrant capacity. And this was touched on in the report referred to by Dr. Hollomon, the Charpie report, the first definitive study of innovation in the United States. The report cited a few characteristics of local areas that are conducive to the innovative process, such as availability of capital and types of people present.

I would submit, Mr. Chairman, consistent with the thoughts I was trying to express, that one of the important ingredients possessed by these two areas is the very intensive interaction between the local industrial community and the academic community.

It is probably no accident that MIT and Stanford University, two of the major universities in the country, have an enlightened and encouraging view of involvement with local industry on the part of their faculties, rather than looking down their noses at it as though it's a tainted activity. The type of offering that's being proposed in your bill, as well as the thinking process going on on the part of many of our staff, requires more intensive involvement between the universities and industry and should look to those very successful example on Route 128 and Silicon Valley.

Further to that, I would like to add that a characteristic that one finds growing interst in, alluded to by Professor Mead, is the spinoffs from companies. There was a time when large corporations took a terribly dim view of some of their more entrepreneurial-oriented people taking an idea and going off and forming a company. Today, many companies are encouraging that so that they can get the benefit of the creation and invention and the R. & D. that is present in the large company and the entrepreneurial spirit, and ready attractability of outside capital that's a characteristic of the small enterprise. And the more that can get done, the better it will be.

Senator STEVENSON. You have all described a complex innovation process, and it may be even more complex than you described. At least it seems to me that this marketplace, a global one, is influenced by many persons, by forces which were never recognized by Adam Smith—and still aren't by his descendants. It's influenced by governments, by religious movements; it's a creature of history, politics, resources and scarcity of resources—of forces for which there is very little precedent.

Hence, market researchers and economists have done a very bad job, I am told, of predicting inflation rates, predicting, particularly in the United States, market opportunities. Automobile manufacturers might still be making gas-guzzlers if it had not been for the pressure of Government with fuel efficient standards.

Yet, Government in the United States is generally regarded, at best, as irrelevant; free enterprise is generally regarded as omnipotent.

What should the role of the Government be in this process? Government is not irrelevant, exactly. It's looked upon as a source of funds.

Mr. Throdahl's chart, as a matter of fact, conceives of Congress authorizing funding for the Office of Industrial Technology, and we've got dollar signs and money going from the Government to the centers of excellence, and then out of the centers of excellence goes knowledge.

Well, what I want to get at is whether more than money shouldn't be forthcoming from the Government in the products we have. We have, of course, a legitimate interest just in accountability for the funds we collect or transfer to universities and industry. But also in this world in which Government is creating the market, whether the Government shouldn't have some role in picking the markets.

Let me cite a couple of examples of experience. I was in neither of these houses in 1956. I was at Harvard Law School. Then I entered politics and discovered a very different perspective, and also had some experience on this committee. In the last Congress, we deregulated the airline industry. I found myself sitting here creating a new market—a market for short-haul commuter aircraft.

So, we called NASA, for which we have some jurisdiction. I suggested that they devote some attention to assisting industry with developing the whole new generation of aircraft, not only for the United States, but for the world markets.

Well, we talked to NASA. I raise this because Dr. Goldman brought up the precedent of NACA, and I know Dr. Holloman mentioned the aircraft industry as one of our most competitive, dynamic industries.

And you, Dr. Holloman, mentioned how the efforts were coming back not very long ago. They said the problem is with industry. The Brazilians are moving in to supply the market; the Canadians are moving in; the British are moving in; and now the Russians are moving in.

They were showing off their commuter aircraft at the Paris air show a couple of weeks ago. They're licensing Russian technological experience here in the United States. American industry is too busy making DC-10's to move into this, I think, still potentially very large market. In the meantime, the DC-10's are getting competition from air buses.

I certainly don't mean to suggest that Government is perfect. The Government has some responsibility for decisionmaking—Concorde—but in those other countries that have been referred to, the Europeans and the Japanese, there is a cooperative relationship between some of those, and some involved Government in a cooper-

ative effort, not only to provide money, but also provide knowledge and some participation in the decisionmaking process: Where the R. & D. goes, where the opportunities are, and what the Nation's priorities are.

The Japanese decided to go into the semiconductor business. They considered the resources—their labor force—and considered their environmental requirements, and they decided they wanted to become a knowledge-intensive country and move ahead and go beyond, and ended up passing us.

Well, I am sorry I took so much time, but I think we have not addressed this question in the bill, and I really don't know how it should be addressed.

Do you have any reaction to those observations, Mr. Throdahl?

Mr. THRODAHL. Well, it might be instructive to go back in time and look at the conditions that led to the Morrill Act.

Senator STEVENSON. To the what?

Mr. THRODAHL. The Morrill Act. That was the beginning of a Government partnership with agriculture and the formation of the land-grant colleges. That led to a baseline that permitted agriculture to move—right after World War II—to the preeminence it is in today in the world.

I don't think that, in the absence of the Morrill Act and the results of it which the Government really was a leading partner at that time, that our agricultural situation would be today what it is.

I haven't studied that act, but I do know that it is one of the landmark cases when you look at innovation. It was more than just simply a technical innovation. It was an innovation in education which built this great background for what we've got today.

That might be an approach that would be worth doing.

There are a number of industries today that are ripe for this kind of approach because they lack capacity for instigating changes in procedure or equipment.

Now, you know, there are tradeoffs on that too, because there would have to be movements of population, retraining of people, and so on. But that's what this bill is all about; isn't it?

Senator STEVENSON. Dr. Mead.

Dr. MEAD. I guess what I was suggesting in my testimony was a new role for Government. I think it's a very important role and it's one that simply can't be done by private industry in the way we know it today—and that is a way of spotting time when innovation has come to a halt because new ventures can't form for lack of essential service or availability of some essential manufacturing technology or something like that.

I think that it is going to happen over and over where a thing that a firm needs to be in the business becomes more and more expensive, that finally the little ones can't afford to do it themselves anymore. And there is really no incentive for a large firm to make it available to the little guys, except good will or enlightened management or something, which you can't always count on.

I think the Government can have a very key role in watching for situations where the cost of entry into a business has gone up to the point where new ventures can't form in that industry and to look at what might be done about that. And I think that the

semiconductor today is only one such example. Surely there must be others.

Senator STEVENSON. I think our free market now assigns a higher price-earnings ratio to the stock of Ceaser's Palace than for Xerox. Do we leave it all to the free market?

Dr. GOLDMAN. I prefer not to comment on how the financial community assigns price-earnings ratio to stocks.

However, responding to your earlier comment on the question—I think there is a very important role for the Government in this area beyond that of providing dollars, and in a sense it's inherent in our proposal for the creation of these centers of industrial technology. I need not tell someone with origins in the Harvard Law School that in our culture there are always problems associated when companies get together, particularly when they're getting together for the acceleration of technological innovation.

The centers for industrial technology and such institutions as NACA and NASA bring companies together, and the Government involvement here must be, in addition, one of being a gatekeeper, if you like, to the group that sits in to make sure it is accomplishing its purpose in the furtherance of innovation and the furtherance of the needs of the country, and sees it also maintains, let's say, the honesty of the poker game so that at no time will there be concerns as to whether this is violating the spirit of free competition that has built up our country, but which is not encountered by either the Japanese firms or West German firms or the U.K. firms that we look to who create the competition you referred to, and certainly not by the Soviet aircraft industry.

And so, if we are to look to an opportunity for centers in which the technology transcends the specific parochial interests of a given company, the Government's role is terribly important.

Senator STEVENSON. Dr. Hollomon?

Dr. HOLLOMON. There are several factors that have to do with the role of Government with respect to industrial development. One you mentioned yesterday in your talk before the AAAS is the long-term adversarial attitude between certain elements of industry and Government.

I hope and believe that is changing and changing for two very important reasons. One is this country will have to trade—until recently we didn't have to buy much from outside, and we didn't have to sell much abroad in order to have a viable economy. The Germans and the Japanese, the Swedish, the Swiss—all have to sell a very substantial fraction of their manufactured goods outside their own countries in order to survive. That condition requires a cooperation between Government and industry. It can't be done without it. There are too many political questions having to do with trade and industrial development.

The second factor affecting cooperation between given and industry is partly addressed in this bill. We have never provided the resources to Government to understand what was going on in industry in the first place and therefore there was distrust. This bill, in its studies of sectors and technology and how industry operates, provides, it seems to me, some further knowledge to the Government that makes it possible to help make wiser industrial judgments.

If we are to devote Federal funds to industrial technology, then I do think it's appropriate for the Congress and the executive branch to understand where those funds are applied, and broadly speaking, not in detail—in what areas we might concentrate. And I think that's a responsibility of Government.

Senator STEVENSON. Senator Schmitt?

Senator SCHMITT. Thank you, Mr. Chairman. And thank you gentlemen for a very stimulating interchange of ideas.

One thing that we haven't talked about is that when you do get a group of people together, exchanging ideas on a particular subject, more often than not, the Senators that are there create. I think it's characteristic of this discussion this morning.

Now, I want to set aside for the remainder of my discussion those policies that have inhibited innovation outside of the creation and use of technology. And I am speaking there of regulator policies, tax policies, patent policies, and so forth.

I think if the truth were known, we would find that these were far greater inhibitors than most of what we have been talking about today. And it could be that under the umbrella of the legislation that Senator Stevenson and I are looking at in this legislation, that we could come to grips with some of those problems too.

What I would like to go back to, though, is the best organizational way to accomplish what we want to accomplish. The example that Dr. Goldman gave of the NACA and the example already mentioned by Mr. Throdahl of the agricultural revolution I think may show us, the way in which we can set up the innovation process. They were organized differently. In one case, the dependency was on a college system, a very local concentration of expertise on local and regional problems. In the other case, the Government centers were established at Lewis, Langley, Ames, and so forth. And it may be that the combination of the two, which I believe in very broad outlines that the bill does contemplate, that we may have our answer.

But it also may be we need to become more specific based on the success of those two experiences—on how we actually organize and manage such innovation centers.

Now, I would ask for your comments on that. Also I would like your comments on whether or not we might be trying to be too broad. One reason that the agricultural revolution was successful was because it concentrated on agriculture. One reason why NACA was successful was because it concentrated on air transportation. At least that may be one of the reasons why they were successful.

If you talk only about innovation, we may be trying to do too much, whereas if we look at a variety of types of centers, separated according to category, such as energy centers. This approach was used in NASA just a few years ago in applying the old NACA laboratory concepts to energy research and development. This was done on a much more modest level than things should be done. We might look at transportation, electronics, and information management. In fact, a critical problem is developing in strategic alternatives for resources that we now import and are dependent on. But we'd better start thinking about what our alternatives are in case we can't get those imports.

So there are a variety of breakdowns that you might come up with. But would you comment on whether you think a combination of the NACA and the Morrow Act concepts might be a way to go for these centers and whether or not we don't need to be a little more focused in the attention of these centers.

Dr. GOLDMAN. I think, Senator, one of the reasons I find the bill introduced by Mr. Stevenson and yourself so attractive is that it talks specifically of that. I believe the centers of industrial technology, in a way, latter day embodiments of what was contemplated when NACA was organized many years ago in joining the forces between segments of our society in order to accomplish a specific task. Therefore, it is attractive.

Now, I believe your second concern on how do we focus on prioritization of desirable goals. Hopefully this will be accomplished by the other parts of your bill that call for the creation of an Office of Industrial Technology to assess opportunities, to look to strategic needs on the part of the country, and not to try to find band-aids for today's problems in a specific given industry.

An interesting aspect of the industry that was described for us this morning by Professor Mead is the fact that the emergence of the solid state semiconductor industry is the product of something that is not unlike the emergence of the success of our aircraft industry.

As I mentioned in my comments earlier, the discovery, the original discovery of the transistor—not just a light going on in the head of an inventor but was strategically planned and was directed by Bell Labs, that had the charter of worrying about the communications needs of our country. And way back in the 1930's, they anticipated that the vacuum tube would have to be replaced. It had neither the reliability or the frequency characteristics that would be required to carry on traffic for all the needs—the band width needs of the future—and they were looking and mounting a program to seek alternative means. The transistor was the transition point at which they changed technologies.

Then, as the transistor emerged and its follow-on first with germanium and then with silicon, the future was largely predictable.

But the technologies were not completely under control. One interesting aspect of this industry is that 12 years ago we were trying to predict almost precisely the cost of electronic storage and logic. And to this day we have kept pace right on with those predictions. The technology has been assured to a large extent by the ordinary forces of the marketplace. However, in the areas where there is no custodian today for a single technology that is of great importance to us, I would expect that the Office of Industrial Technology would anticipate those areas that will become of such importance to us that we ought to create these future NACA's in the forms of specific centers for industrial technology. And this in a sense talks to the question raised by Mr. Throdahl.

I would see not a myriad of these centers but rather a few very specific, strong centers in particular industrial areas of vital concern to the economy of this country, and they would be built up in a manner that was suggested.

Senator SCHMITT. Dr. Goldman, I am concerned that we seem to indicate that we don't know the areas that we need to focus on

right now. And we picked aeronautics as a place that needed to be focused on many years ago. We picked agriculture as one. These were good decisions.

The question is should we say that we need a national advisory committee for energy which would have a few centers that would work in a focused way, rather than having some other body determine the priorities, and distribute parts of the pie among all centers. But that's what I'm concerned with. We have already seen in the national laboratories of DOE and the national laboratories of NASA an overproliferation of tasks among the various centers. Where competition is good, there is no question that competition is good among Federal centers or centers of these kinds.

Nevertheless you can give them too much to do. You can spread them too thin. You would still advocate that the Congress not try to make these decisions at this time?

Dr. GOLDMAN. I don't think it would be appropriate for the Congress to make those decisions. But the Congress is creating an institution to be able to make those decisions.

Senator SCHMITT. Why can't we make those decisions?

Dr. GOLDMAN. Because I think organizations that are staffed for the purpose of being able to make such decisions make more sense. Would you like to have the staff of this committee or the staffs of the Congress sit and perform the technology studies, assessments, futurism that's necessary, without bringing into the process the various constituencies of our society, namely industry and the universities to make those decisions?

Senator SCHMITT. No, but we could make the decision whether we need to have centers that are devoted to energy. We can make the decision whether we need to have centers devoted to strategic materials.

Dr. GOLDMAN. I am not sure we can make the decision today on whether we should have a center on welding research. Yet a month ago——

Senator SCHMITT. You could go so far as to say in manufacturing research and I really am surprised at this. I think there are general categories that Congress must make those decisions. And we can't through processes like this.

Should we focus on welding this year or should we focus on the production of semiconductors?

That is another thing that the advisory committee should clearly do.

But to make the decision on what are the critical national needs? I think that is the function of the Congress.

Dr. HOLLOMON. A comment first about agriculture. Consider the time when the Congress took on the task of providing the infrastructure necessary for agricultural development.

At that time agriculture was the business of the United States and 60 percent to 70 percent of the people employed in the country were involved in agriculture. The Congress didn't decide that it was going to have institutes for corn, institutes for wheat, institutes for tomatoes and institutes for the other agricultural products. It didn't create a single center for agricultural research for grain products or pigs.

I think it would have been a horrible mistake had they done so.

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Senator SCHMITT. I agree with you. But it picked agriculture.

Dr. HOLLOMON. You are picking industry. That is enough. One is as complex as the other. Agriculture is as complicated as industry. Industry is as complicated as agriculture.

The importance of this legislation, I contend, is that it finally recognized the importance of industrial technology.

I have two comments. I want to disagree with my colleague on my left. I believe in the recent discussion in the last few minutes there was too much attention to technology as if we are trying to create a few things like aeronautics or manufacturing or the like. That is not the problem of this country. It is only one of the problems.

Small firms and medium-sized firms and even some large ones don't know well how to deal with energy, with materials, with conservation, with production, with manufacturing.

If we could simply manufacture and sell as well as we know how, productivity would be enhanced.

The great success of the agricultural program in my view was not just the research done at the land-grant colleges and research institutes but it was the teaching of know-how by the extension agent.

Senator SCHMITT. No question about that.

Dr. HOLLOMON. What we have to have and what this bill implies, though I think the emphasis has come away from it in the last few minutes, is a series of institutes throughout the country—I insist they don't have to be institutes—a series of activities throughout the country—which not only develops new technology that is pertinent to economic problems, but has a sophisticated extension program.

That sophisticated extension program can't be designed in Washington. It can't be run by Washington. It has to be related to the industrial characteristics of the region and the place. Not unlike agriculture.

Now, on the other hand, you say that there is some concentration needed. I agree with you. I think the way to get this concentration is to have placed around the country proper what they would intend to do.

I believe that new manufacturing technology, particularly in the light of the computer revolution, is the single most important area for development.

We have a chance, it seems to me, to implement change and modernize and restructure the manufacturing industry in the country.

I still wouldn't mandate work even in this area. I think what ought to happen is that the new office you mandate, through advice and counsel with the Congress and discussion with the Congress, ought to see to it that at least several places in the country have a sophisticated manufacturing activity.

Let the interplay between the industry, universities, new Government office and the Congress decide where the priorities ought to lie.

I would like to say a few words about central Government laboratories. I believe that in the field of economic development, our country is so large and so complex that the likelihood of one or two

Government labs being effective in the area of civil industrial technology is small.

Second, one of the great reasons of connecting these new institutes with universities is to enhance the training of people for industry. That is an important element of this program.

Senator SCHMITT. That is exactly why I think it is a combination of the two kinds of mechanical systems. The land grant college, but also looking at the lessons learned and how you actually make things happen from a detailed managerial point of view.

Dr. HOLLOMON. If one examines the structure of research throughout universities in the agricultural program, you will find that they do concentrate in different areas.

Programs in Kansas are clearly different from the programs at Cornell. The California land grant colleges are basically and fundamentally different from the programs in Georgia.

Senator SCHMITT. You make excellent points. My only concern is that having watched the bureaucracies move off in directions or without direction, I think it is very important that we in Congress not abrogate our responsibility to provide the guidance. They don't have to run for reelection and we do. There is a big difference in the objectivity with which an issue is treated.

Dr. HOLLOMON. I don't disagree with that. I am just concerned when establishing institutions with particular emphasis in a few years the mission will be gone.

Senator SCHMITT. I don't think we basically disagree. At least I didn't disagree with everything you just said.

I do, however, feel that there may be broad general categories in which the Congress can establish the guidance. I completely agree with you that we should never foreclose reasonable diversity because that is exactly what we must have. This country is still rich in diversity.

Did somebody else want to comment on this?

Dr. MEAD. I would like to point out that one of the places that innovation could go on very nicely is in the proposals for these centers. There are some very smart people out there who are interested in innovation, and they will construct some very innovative ways to use a piece of legislation like this to get some innovation going.

I think that one needs to kind of trust that there are such people out there, but I think there need to be guidelines for how you select these things when they come in. What do you mark highly and what do you mark poorly? We are not talking about a very large amount of money and it is easy to spend it in such a way that you don't get anything back for it.

You must in some way match the amount of funds there are to the real task that is there and see that you really get something back for it. Not just, "Well, yes, we did a little research here and there."

So I would urge that something be said about the way these proposals would be evaluated so you get the most "bang for your buck" and let the innovation of these folks start showing itself.

Senator SCHMITT. Let me go to one other point. Dr. Hollomon, I noted in your testimony you referred to the nuclear reactor failure and the DC-10 failure, and it implied a failure of technology.

I may have misunderstood you.

Where I think certainly in the case of the nuclear reactor failure, so-called, they are really a failure in the management of technology. Certainly not in the reactor itself.

But more importantly there, in the management of the technology of power plants. It is not confined just to the nuclear industry.

In New Mexico the last couple of years we killed several people in coal-fired plants. A failure in the management of technology, and not the technology itself.

It is looking more and more like maybe even the DC–10 situation is not an inherent difficulty with the technology by which it was created, but a failure in the way we managed that technology, or even maintained it.

So one of the reasons I bring this up is that there is an area of innovation which has been rampant, as a matter of fact, the management of technology, in the last two or three decades. Independent, almost, of the technology itself.

We have learned a great deal how to do things right. Quality control, for example; the overall issue of how do you make things work, how do you do things right.

We don't always remember those lessons. We certainly haven't yet learned them in the nuclear industry. We can learn them. We learned them in space by killing three people in the Apollo fire. Then we went to work doing what we knew how to do but started doing them right.

Do you think this is an area that must also be kept in our mind in addition to the hard technology itself?

Dr. HOLLOMON. Two comments. There is a perception of the failure of technology on the part of the public.

Let me say what I really believe. I don't believe that we have paid enough attention to quality control in this country in nonspace, nonmilitary applications.

I don't believe that we have, for example, an attitude in the factory or people who are engineers as skilled, for example, as some of the Japanese relative to quality control.

I am on the board of a company that has both a Japanese factory and U.S. factories, and I will tell you that there is a substantial difference between quality control techniques and the attention paid to them in Japan from what there is in consumer products in this country.

I don't know whether the DC–10 failure was a failure as a result of poor maintenance practice, nor would I say that that is evidence of a great decline in American technology.

I will say that it is in the people's mind perhaps it is. Not necessarily in the real failure, but in a perception of a failure. So I want to say two things: If you go to the American universities that teach engineering, one of which I happen to be a part, and find out how much is being taught about quality control, about manufacturing, about inspection, you find almost nothing.

I think that we have given far too little, both management and technical, attention to the fact that goods have to be manufactured reliably, of high quality, at reasonable cost.

So I think there are two problems. One is a problem having to do with management—it is not true with every industry. And the other has to do with technology.

If this new program will contribute a lot of mundane things like quality control, as well as sophisticated things like silicon chips.

Now, they are not exclusive, either. Chips and microprocessors and methods of decentralization help you with the quality control problem.

Senator SCHMITT. Can I interpret from what you say, that you think it is the management of technology that is as important an issue as the technology itself and can't be separated?

Dr. HOLLOMON. True. But also the teaching of those who have to do that.

Senator SCHMITT. Of course, and that the center shouldn't in any way be precluded from, maybe in fact should be encouraged to, including in their overall activities these issues.

Dr. HOLLOMON. Absolutely. That is why I say I was a little distressed by an early conversation concentrating on technology at the forefront and not so much on those things that are crucial to making superior products at reasonable prices.

Senator SCHMITT. I am sorry to distress you. My only intent in directing that original line of questioning and comment was to explore just to what level should the Congress be acting to subdivide the activities that might be undertaken by centers as proposed.

As you have indicated today in your own testimony, it is a very broad subject. Is there a subdivision of innovation which we could make in the Congress in order to make sure this moves in the direction we want it to?

Dr. HOLLOMON. I would think, since we are starting an innovative activity, that if in a couple of years, for example, methods of design and quality control have not been emphasized in the programs you initiate, if I were in the Congress I would see to it that they were.

Senator SCHMITT. It is often harder to get things changed than to try to do it right the first time.

Did somebody else have any comments about the quality control or management issue?

Thank you, Mr. Chairman.

Senator STEVENSON. We held hearings on recombinanted DNA not long ago and, as a result of our studies on that subject, we were all impressed by the commercial possibilities of genetic engineering.

I happened to mention this possibility to a friend in the banking business and he told me afterward he would follow it up. He said he would look at it and see if there was any investment opportunities. He said, "Well, I located a small company out in California that looked very promising but there was no way of getting into it."

Then he talked to a large drug company which said that they had gone to the same company and hired away some of its scientists and were locating them all over Switzerland, because the climate for innovation was more hospitable there. There wasn't the threat of regulation that existed in this country.

Now, getting back to the chart, are these lines which have money flowing from the Government—well, from Congress to the Office of Industrial Technology, and then to the centers, going to produce knowledge that goes out to company C in Switzerland, company B in Japan, company A in the Netherlands?

Who will we end up doing this for? Is there any assurance that, inhospitable as the tax climate and regulations are, bothersome as we Members of Congress can sometimes be, other countries now are more sensitive, as Dr. Holloman and some you of indicated.

Dr. MEAD. My own perception is that there is no way to hide any of this stuff from anybody. You are kidding yourself if you think that we can lock it up inside our Government laboratories or inside our little firms. It is really just a matter of time. It is a matter of lead time.

Yes, there will be innovation done here that goes to Japan and goes to Switzerland and other places.

There is certainly nothing that can be done by way of stimulating innovation here that takes the place of creating a good climate for ventures to grow in as they come along. You really have to do both things.

By the very nature of our business, we educators see to it that information will get around.

On the other hand, we learn some things from those people, too. We are learning a lot from the Japanese right now. I think you simply have to do both things. You have to make a hospitable climate for things to grow and also have to make sure you stimulate the initiation of that growth.

Mr. THRODAHL. I am not bothered by that comment, either. I was only trying to make a different point.

But suppose 90 percent of the innovations stays within companies that are basically U.S. oriented and 10 percent are somehow or other siphoned off in some way. There might be ways to obviate even that, but that won't bother me very much.

I am surprised at your story that the drug firm found more hospitable climate somewhere else. I would try to find out why and see if that could be used as a learning experience.

Having part of the innovations commercialized elsewhere really won't bother me much. I think there are ways to control that sort of thing in our favor.

Dr. HOLLOMON. If we don't do a number of things, I believe if we just simply supported basic science and technology in the universities, without a great deal of care the greatest beneficiaries may be the Japanese. If we don't do something else.

That is why I tried to emphasize the studies we have done for OTA and others, that the important thing is our ability to translate quickly and at the right time those things in commercial practice.

If we don't do that, the investment in generally available information will be lost. I am concerned about that. I am concerned about the climate for establishing of new firms. I am concerned about the inflation rate and what that does to existing firms with respect to investments in the future.

The majority of the research and development in the world will be done outside the United States. It is already true. It is true right now.

We have to learn how to first know about what is going on in the rest of the world. Science and technology is a funny business. If you don't have the ticket provided by participating, you can't find out what the other fellow is doing.

One of the purposes of this is to be sure that we have some people with tickets.

Senator STEVENSON. Tickets?

Dr. HOLLOMON. In other words, for me to know what is going on in West Germany, I have to be a participant in the process of science and technology in order to find out what they are really doing. I have to have an admission ticket.

The second point I would like to make is that I believe that the matters not touched upon in this bill, which you have mentioned—patents, venture capital, tax policy, antitrust policy—need to be quickly tended to to ensure that our companies, yet unborn and already born companies, can effectively exploit what we know.

If we don't do that, we will do what England does. They have a first-class research establishment. They have had for a very long time. Their difficulty is, for lots of reasons, a lack of commercial exploitation.

To me there is a great benefit of the English research. We use it. Or have. They have used it, too. But not as effectively.

I have a great concern with your concern.

Senator STEVENSON. I think you made your point very well. The concern is a broad one. The effort requires many measures to improve the climate.

Senator SCHMITT. Mr. Chairman, if you would yield, I think what we are hearing here is that because of the accelerating rate of change in our society, any company or any country that is going to be successful has to maintain a dynamic stability far in excess of anything ever before required.

A steel industry could develop and amortize its investment and replace plant in the last century and go on and on. Now that time constant, rather than a 30- or 40-year period, is in terms of a year or two or three.

Unless we in industry and in Government, recognize the need for that dynamic stability rather than a static stability, we aren't going to make it. I think that is what is being said.

Mr. THRODAHL. I have a couple of suggestions here. One would be that I think three of us—I don't know about Dr. Mead—participated rather intensively in the domestic policy review on innovation which is now going to come to some fruition in the near future.

Senator STEVENSON. Is it? I am glad to hear it.

I would be delighted to hear from all of you about your expectations of that.

Mr. THRODAHL. Put it on this basis: I think that the recommendation from those seven subgroups came to in excess of 150 recommendations. Some overlapping.

If you squeeze them down and sort them out, you come out with about two dozen recommendations that encompass a great many of

the things Dr. Hollomon and Dr. Goldman alluded to, and would go a long way toward making S. 1250 more viable.

I think you ought to wait until the domestic policy review results come out and see what happens. All of them don't cost money to implement.

The second point I would like to make is that if I somehow got the job of being director of this—this Office of Industrial Technology, if the bill passed, what in the world would I do?

Maybe it would be worth a trial and error approach among your staff groups to say: Well, how many standards of excellence do we envision? Let's try some just by setting them down on paper.

Certainly you might talk to some people like ourselves who testified here, and others who will come, on paper just to see whether or not the stuff hangs together along with what comes out of the DPR.

Senator SCHMITT. That sounds like a revolutionary concept. Something you might call simulation applied to legislation rather than just engineering ideas.

I think it is a good idea.

Mr. THRODAHL. Thank you.

Senator STEVENSON. Did you want to be heard on that, Dr. Hollomon?

Dr. HOLLOMON. I don't know. I would just——

Senator SCHMITT. I think he was shaking his head as we often shake our head at domestic policy reviews.

Dr. HOLLOMON. I have been around a long time and I have been waiting for something like this since 1962. That is a hell of a long time to wait. I don't know whether you should wait for the domestic policy review.

The major thrust of this legislation is to initiate an activity that is devoted to improve the industry of the country and that our security is as much dependent on that as it is dependent on weapons.

I would think through hearings such as these we could proceed, whether or not something comes out of the domestic policy review.

I don't know what is coming. I don't know when it is coming. I guess I am just impatient.

Senator STEVENSON. With good reason.

Senator SCHMITT. One question, Mr. Chairman.

I have more questions that I would like to have you answer for the record related to some of the issues I mentioned but we didn't really discuss.

I would like to ask one final question. Do you have concern over our essential self-sufficiency and variety of technologies as well as material technologies?

Are we in a position now where, because of an interruption of the availability of supply abroad, that we could cause serious economic disruptions?

Energy is an obvious example. We know about that one. Are there others beside energy? Should we be concerned about this?

Should the director of these centers be concerned about this?

Dr. HOLLOMON. I think, obviously, there is a clear case for several metals with which we should have concern, not the least of which is chromium and cobalt. There may be others. There are

others. Here I think we should—it is not just a question of the technology. It is a question of stockpiling. It is a question of substitution.

Certainly I would see some of the activities involved in this kind of program devoted to both substitution technology and questions that are related to stockpiling, which is a technological question but also is a question relative to how do you protect yourself against serious interruption.

Senator SCHMITT. Are we also in some more specific component technology, and especially materials technology, hitting similar bottlenecks if those imports become unavailable?

Dr. GOLDMAN. I think we have to be always sensitive to those materials—I think we are thinking now today mostly on real physical materials when we think of technological limitations.

Dr. Hollomon mentioned the question of subsitution. If an industry or a technology is heavily dependent upon a series of materials—a material, several materials—it becomes a national problem to be concerned as to whether there is an infinite supply.

To cite a specific example from my own company, the machines on which my company was built up depended heavily on selenium. There was a period approximately 9 or 10 years ago when we grew concerned about the availability and access to the selenium resources of the world.

Having extensive R. & D. programs within the corporation, we immediately set ourselves the goal of finding alternative substitutes for the business end of our machines, the photo receptors.

We have effectively solved that problem, as have some of our competitors.

I can see a situation arising where other institutions, not necessarily blessed with the benefit of extensive R. & D. facilities to solve this problem on their own, I think it becomes one of the goals of this new office—perhaps even OTA plays a role here—to assess our future dependence on certain critical materials.

I can't off the top of my head right now cite them. One program that Dr. Hollomon played a very prominent role in its development in an earlier incarnation of his with the GE Co. was finding a synthetic substitute for diamonds, which are so important in our manufacturing processes, anticipating the fact that we don't control the source of supply of diamonds and don't know what the future might bring in that case.

There are undoubtedly other materials in this category. I believe the National Materials Advisory Board is conducting such a study for the National Academy.

Senator SCHMITT. Do you sense a lack of component resources as well? I keep hearing stories that there is only one supplier left in the United States of this particular component or that particular technology ingredient. Do you sense that that is a danger we face?

Dr. GOLDMAN. If you are distinguishing between materials and subsystems, components meaning assembled components, I can see that kind of situation arising where a specialist, say, in Switzerland has evolved a technique of manufacturing some very fine components which we don't have and if that source of supply disappears, the whole product has to face acute shortages, delays,

and sometimes inability to get to market. I have known of experiences in the past where this happened.

I think this is not so much a breakdown of availbility as it is a breakdown of—not breakdown, but an art or a culture which grew up in some other country not our own, such as the ability of the Swiss to do some very fine mechanical work that is not easily available in our country.

Senator SCHMITT. Thank you.

Senator STEVENSON. Thank you, gentlemen. This has been a very useful, helpful exercise for us.

The committee is adjourned.

[Whereupon, at 11:55 a.m., the committee was adjourned.]

# THE NATIONAL TECHNOLOGY INNOVATION ACT

WEDNESDAY, JUNE 27, 1979

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
*Washington, D.C.*

The subcommittee met at 9:35 a.m. in room 6226 of the Dirksen Senate Office Building, Hon. Adlai E. Stevenson (chairman of the subcommittee) presiding.

Senator STEVENSON. The subcommittee will come to order.

Good morning.

We continue our hearings on industrial innovation with particular reference to S. 1250, the National Technology Innovation Act. This bill is an initial legislative step. It is not intended to be a comprehensive means of enhancing innovation of American industry, but it is intended to improve the ability of universities and industry to collaborate in centers for industrial technology, generating new technologies for the marketplace, and it is intended to improve the Government's ability to assess technical and economic conditions that determine productivity and employment in specific industrial sectors through an office of industrial technology.

One of the witnesses scheduled for today will not appear. He will appear later in this series of hearings, but I expect soon, and he is Dr. Baruch, the Assistant Secretary for Science and Technology in the Department of Commerce.

We are very pleased to welcome the witnesses to this committee and thank you for joining us and sharing with us a good deal of experience with the subject.

Our first witness is Dr. Richard C. Atkinson, Director of the National Science Foundation.

I will say to you and to all of our witnesses, Dr. Atkinson, if you would just summarize your statement, I would then be happy to put your full statement in the record.

Please proceed.

## STATEMENT OF DR. RICHARD C. ATKINSON, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. ATKINSON. Senator Stevenson, I very much appreciate that advice; I would like to enter the statement into the record.

Senator STEVENSON. Without objection.

Dr. ATKINSON. I will make a few remarks, and I hope that most of our exchange can be in the form of a dialog, with questions, as you see fit.

I must say that I find S. 1250 extremely interesting, and I am particularly intrigued by the efforts in the bill to make university

and industry research more effective. The coupling of industry and university research activities is an area that NSF has been particularly concerned with in the past several years, possibly dating back as many as 6 years. Certainly in the past 2 or 3 years, we have designed some specific programs to improve such coupling.

One can conjecture about what happened in the 1960's. I would argue that there was a decline in links between university and industry research activities. There were several reasons: The natural job market for Ph. D.'s was moving into universities rather than into industry, and ample Government funding for much of the university research made industry connections less important. There also were reasons on industry's side that led not only to a reduction in the level of basic research supported by industry in the 1960's, but also to a reduction in the links between universities and industry.

In any event, I think reestablishing and strengthening those links is important, and your bill indicates one area for more effective effort.

Now, why are such links important to industry? There are a number of reasons. Industry needs to be aware of the latest research going on in the universities. Industry also needs to help shape university research so that industry can affect the nature of research conducted at universities. And industry needs to help shape the training of undergraduate and graduate students in science.

In turn, universities obtain a great advantage—or a great payoff—from such links. Universities are aware of research in industry, aware of industry's problems, aware of the job market for students coming out of the universities, and aware of industry as a source of funding for university research activities.

It's in the interest of both universities and industries to once again establish those links; there is evidence throughout the country of quite a bit of such activity. For example, I visited MIT about 4 weeks ago; I was surprised by the number of projects—even large-scale efforts—being planned or already tipped off between university and industry.

NSF's programs to stimulate university-industry interaction fall into several areas. One is what we refer to as our university-industry cooperative research centers.

Dr. Suh is here this morning from MIT. He is the director of the MIT Polymer Research Center, a center initiated with NSF funds. I am pleased to say we no longer provide funds. Industry now is providing about half a million dollars a year to support that activity.

The beauty of it is that there are close ties the various companies involved, the directors of research in those companies, and the researchers at MIT. The feedback facilitates research at MIT and provides useful approaches for industry research.

I can give other examples of universities-industry cooperative centers, but I prefer Dr. Suh to describe the MIT center and possibly answer questions.

I think such centers are somewhat like those spelled out in S. 1250, and I am pleased that we have experimented with activities of this sort and find them valuable.

Another area of NSF effort is what we call industry-university cooperative projects. Here we welcome joint proposals from scientists in universities and scientists in industry for either basic or applied research. These joint proposals are evaluated against all of the proposals received by the Foundation, but primarily against proposals from the universities, for their potential scientific contribution.

The key aspect of a joint proposal is whether it will generate a link between the university, science community, and industry. The quality of these proposals—the excitement of these proposals—is surprising to all who have been involved. My written testimony lists some of the joint projects now in progress. By such programs at NSF we can foster and stimulate cooperative research.

Another area that we have been concerned with is small business innovation. In this program, a small business can come to the Foundation for a first phase grant of $25,000 to pursue a research idea that could be pushed into development. That $25,000 is really nothing more than seed money to investigate the idea's potential.

If phase I is satisfactorily completed, the small business can come back for phase II, an additional year of funding at a somewhat more substantial level. For phase II evaluation, the proposal must be far enough along to indicate sources of venture capital for pursuing the innovation into the marketplace.

I have been surprised by the responses we have received from small business. We already have underway a number of activities that I think are very real possibilities. The program is a very small investment by the Federal Government, it is competitive, and there is no long-term commitment by the Government.

A fourth experiment is our innovation centers. A number of people here this morning have been involved with these centers: At MIT, Carnegie-Mellon, the Universities of Oregon and Utah. I won't describe them, except to indicate that the centers are concerned with activities that foster the movement of research into application. I think they have been quite productive.

Yet another experiment is our technology innovation project. Here, when we pursue an area of research to a point where we think some of the threads can be pulled together into a project that could be implemented by industry, we kick off an innovation project. For example, we have been supporting a great deal of research in computer science related to programable automation. We felt the work had reached a point where there should be a major demonstration, and we now have a fairly large-scale project involving Westinghouse Corp., Carnegie-Melon University, Stanford University, and several other universities, to develop a sophisticated computer control system for the production of small electric motors. The system is capable of producing about 90 different types of small motors.

In recent years, NSF has been concerned with centers where we could concentrate high technology equipment. Examples are the Submicron Research Center at Cornell University and several regional instrumentation centers. The idea is that every university cannot maintain state-of-the-art equipment and that some effort to maximize use of such equipment at a few key universities is useful.

I think Dr. Baker, from Bell Lab, testified on some of these points before this committee.

In the submicron facility at Cornell and the regional instrumentation centers we have made a deliberate effort to involve industry. And there is the possibility for industry to use the facilities at those centers. That has worked very well, and I think it is appropriate that university-based centers for instrumentation have that capability of providing access by industry.

I'm going to conclude by saying that I favor the university-industry links, and particularly the type outlined in S. 1250. I would argue that these arrangements should not be set in concrete. I would hope that such centers would have a natural life and would not be continued after that natural life had ended.

In NSF's activities, we try to set the time goal to insure that industrial contributions are not, guided by the bureaucracy here in Washington, but are guided in fact by the best advice received from industry and the universities.

Finally, let me argue that in the area of innovation, I don't think we should be viewing it as a decision to be made on specific courses of action in the next few months, or even in the next 6 months. Rather I think it should be viewed as a problem that's going to face this country for some time. We should view it as a multistage decision problem where we examine continuously the source of interventions that might be useful on the part of the Government. Clearly we need experimental work to be pushed forward by emphasizing stronger university-industry ties and by setting up a number of university-industry research centers. I think that concludes my formal presentation.

Senator STEVENSON. Thank you, Dr. Atkinson. That's very helpful, and you and your foundation are to be complimented for your own innovative efforts to stimulate innovation.

You indicated, toward the end, you thought centers should be of short duration. I think you have emphasized elsewhere that they should be placed on a self-sustaining basis. We have heard testimony that they shouldn't be, on a theory that to do so would drive these centers to produce short-term results, rather than long-term, truly innovative results.

Would you like to comment on that?

Dr. ATKINSON. I have a mixed view. I worry about centers set up so that they continue on Government support year after year and there is really no clear industrial involvement, no clear commitment by both industry and university. One commitment is the clear contribution by industry of significant dollars in support of the activity; another is the clear exchange of people between industry and universities. I think one has to demonstrate a deep involvement on industry's part. Any center that is directed at industry but in fact is a Government-run operation, without real ties to industry, might not contribute.

Senator STEVENSON. But aren't long-term, if not permanent university-industry relations possible?

Dr. ATKINSON. Yes. For example, we expect the MIT center to be long-term. NSF always has had the view that it should provide the seed money, if you will, to get started, but that over time, industry would recognize the value. That doesn't mean there couldn't be

continuing support for a particular project within that center. But the idea of a large staff, a large commitment continuing year after year without a clear input from industry, I would have some doubt about.

Senator STEVENSON. How should the priorities of these centers be determined and how do you view your own efforts?

Dr. ATKINSON. We consult widely on areas of research we think natural for industry-university research centers. That consultation is based on much input from the university community. The IRI has been very useful input for us. And then in the past we have gone out for RFP's, once we have identified a particular area of activity. For an ongoing center, what needs to be clear is that there is a broad input of concerned industry to the center's activity.

By the way, I don't feel that just university-industry centers should be established. At many of our national laboratories, there would be much merit in trying to insure better links—between the national laboratories and the universities and between the national laboratories and industry—and I think several mechanisms can be created to do so without setting them in concrete for all time.

One program I'm sorry we have had to terminate; I thought it was valuable. It was a research program in which university scientists could take a year of postdoctoral work. Traditionally, that year of postdoctoral work has been done at another university. But in this particular program a university scientist could take a year's postdoctoral leave in industry. The scientist would work in an industrial research program. The purpose was to expose the university scientist to the problems and research activities of industry. But it had the secondary input of providing, I think, some stimulus to industrial research.

Senator STEVENSON. Have you had any experience with Cutler National Laboratories with linking them either to university or to industry?

Dr. ATKINSON. I haven't had a direct experience. I just happened to be visiting at Oak Ridge on Monday and Tuesday, and I spent quite a bit of time with the director there, discussing the issue of facilitating university-industry links. For example, in NSF we have regional implementation centers located at universities available to scientists throughout the country—primarily to university scientists, but available also to industry scientists.

I think some of the national labs might do well to have regional implementation centers centered at the laboratories and made available to the use of university and industry scientists. That sort of visiting arrangement to use equipment might facilitate quite a bit of interaction between national labs.

Senator SCHMITT. Would the chairman yield on that point?

Senator STEVENSON. Certainly.

Senator SCHMITT. I think, Doctor, that certainly in the case of Los Alamos and Livermore, the university relationship is very, very strong.

Dr. ATKINSON. Yes.

Senator SCHMITT. I don't know how you would improve upon that, but, unfortunately, there have been some public figures suggesting that the University of California being the principal manager of those two laboratories ought to be terminated.

In the case of the old NACA, now NASA Laboratories, of Lewis, Langley, Ames, there's always been a very strong relationship the other way, and that is the industrial-government cooperation in the development of various aeronautical and testing of various aeronautical systems. The university relationship there might well be improved. It has not been zero, by any means.

I'm not as familiar with Oak Ridge. I suspect there may well have been some barriers to the kind of association you've got to look at since it's managed by an industrial unit—Union Carbide.

Dr. ATKINSON. Senator Schmitt, my remarks were not critical; they were amplifying on the——

Senator SCHMITT. I know that. I just wanted to make sure we had the basis of experience on which to draw upon for this already having been done and already in place. But obviously there are other laboratories where it is not happening as much as it could.

Thank you, Mr. Chairman.

Senator STEVENSON. Well, I'm still a little puzzled as to how the priorities ought best to be established. You certainly can't rely on industry exclusively to do so, or you end up with innovative cosmetics. The record is dismal. In fact, it's been the Government which frequently has changed priority, as in the case of the automobile industry— saved it from itself, although it hasn't been saved yet.

Also, I'm a little perplexed too about possible implications for the universities. The land-grant colleges have been cited as historical precedents generally with respect to the industry that happened in agriculture. The land-grant colleges have received industry support and the innovation that has resulted has been of benefit to industry, and it can be argued now at the expense of agriculture we have produced capital-intensive agriculture industry and the chemical-intensive industry in agriculture.

But productivity in agriculture is declining because of the abuse of the land. Not only higher pollution levels in streams, but the threat to agricultural production in the West.

How do you preserve the integrity of the university research against the bias of industry, as a result of the links that we are groping for?

Dr. ATKINSON. NSF has had a very interesting experience in the area of agriculture and plant sciences. There's no question that the Department of Agriculture and the land-grant colleges have done a good job in many respects in applied research—bringing applied research to the farmer. What became clear to NSF in the early 1960's was that this country's support of research in the plant sciences was far behind this country's support of research, say, in human biology.

NSF, with a small number of dollars and emphasizing the competitive research program, initiated an effort in the plant sciences in the early 1960's that led to a dramatic payoff.

I think most of the work in the Department of Agriculture was supported by NSF competitive research programs in the plant sciences. The area of cloning—single-cell cloning—and some of the dramatic results there in recent years have been supported by the National Science Foundation's efforts in the plant sciences.

What is needed is a balance. We should insure a range of applied work and basic research as a background. In agriculture, one of the problems we have had—in the cattle industry and in other areas—is that the applied research was excellent, but there was not a broad enough basis of research of a more fundamental character to back it up. If this country had had a stronger view in support of the control of pesticides—using means other than chemical methods—I think we would have had a much sounder program.

I am very proud of the NSF's competitive program in the plant sciences. I have been a little unhappy with that—the Department of Agriculture, which has responded very well, now has a program officer from NSF trying to get this program started—but there's been criticism in the Congress that somehow the competitive research program and Agriculture would undermine the other activities. I think that's unfortunate.

I can't help but toss this out—and it may be irrelevant—but you may remember that we were amply criticized for our early support of a project on the sex life of the screwworm fly. It was a fundamental study, opening up new methods of pest control, and not the sort of work to be pursued by a mission agency.

Senator SCHMITT. Mr. Chairman, if I can interrupt, I will certainly support that research on the screwworm, because that is something that affects the beef industry in my part of the country a great deal. Believe me, your job is not through, because it looks like the screwworm is now adapting to newer environments, and we are going to have some more work to do. Not all of the agriculture people agree with me, but the ranchers in my area think it's making a comeback by adapting to new environments where we have not been doing treatment. The same research also has the potential for control of the range caterpillar, which has very adverse effect on the ranch industry. It looks like the sex-related eradication efforts might be successful there also.

Dr. ATKINSON. Perhaps I have made the university-industry research centers sound a little too easy in terms of getting industry input and setting priorities. That's because of the nature of the types of centers that NSF supports. Dr. Suh will certainly have more to say about them, but the work tends to be quite fundamental in character.

As we move toward university-industry activities of a more developmental character, the problem with industry involvement in setting priorities gets more complicated.

Senator STEVENSON. Senator Schmitt.

Senator SCHMITT. Thank you, Mr. Chairman. I think you're right in general about the inability of the major industries in this country to change direction, such as your example of automobile. But I would in a partial defense or rebuttal say that the first steps the Government made, which was to impose a pollution control measure, rather than efficiency measures on the automobile industry, really pushed in the wrong direction for a while. Now I think we're probably moving in the right direction with respect to not only improved efficiency but also a consequence improved pollution control measures, while we just burn more gasoline.

Senator STEVENSON. But there are also fuel-efficiency standards.

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Senator SCHMITT. That's right. That's what I mean. We're belatedly moving in that direction. The first response was, "Let's clean up the stuff coming out of the exhaust. It's actually too bad our first response wasn't to really push to make engines more efficient and at the same time try to clean up the exhaust. But it took us a while to come around to efficiency standards. So the Government isn't always in the forefront in making the right decisions.

And I am very curious, Dr. Atkinson, why the two innovation centers mentioned in your testimony have not been as successful as the MIT center. Could you give us some of the reasons why the centers at North Carolina State and the New England Energy Development Center have not been sucessful?

Dr. ATKINSON. Senator Schmitt, you're going to be surprised with this answer. I did not even know about the New England Energy Development Systems Center. When I read the testimony this morning, that was the first time I had seen it.

Senator SCHMITT. Could you supply for the record some information? You were very high on the MIT polymer processing center as being successful and now self-sustaining. The committee could, I think, use some of the experience from your experimental crucible on why the others did not succeed, if, in fact, they have not succeeded. You may find that they have been more successful than you think, but I would like to have that for the record.

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

The first three experimental University/Industry Cooperative Research Centers were funded by a program (Research and Development Incentives) whose objective was to test incentives that would increase private sector expenditures for Research and Development. Three centers of contrasting design were funded. They were:

1. The Furniture Applications Institute at North Carolina State University. This experiment tested the ability and willingness of a fragmented traditional industry with low historic R&D expenditures to support a cooperative research center. At the end of the 5-year experiment, industry contributions represented only 20% of center expenses in spite of industry acceptance of the new products and processes.

2. The New England Energy Development Systems (NEEDS) Center managed by the MITRE Corporation. This experiment tested the possible brokerage role of a non-profit institution between an industry and several universities. With the creation of the Department of Energy and the sponsorship of another regional organization, this experiment drew funding from the industry only as long as NSF funding continued. Industry contributions were about 40% of the research costs.

3. The MIT Polymer Processing Program. This center served diverse industries, many with market power in their product lines. All of the participants had R&D programs within their firms. The annual contribution by the industrial participants during this first year after NSF withdrawal is more than the entire 5-year grant from the NSF and several times the maximum annual NSF award during the start-up period.

By the program objective, which was to achieve full industry support, only the MIT Polymer Processing Program achieved such private-sector support without Federal subsidy. On this basis, it is the only "success." But from the standpoint of our knowledge about University/Industry Cooperative Research Centers, much was learned from the other two. Chief lessons learned were that fragmented traditional industries would rather copy research funded by others than to fund research which others could imitate. To fund further experimental centers in such industries, there should be strong support from either the industry or from a state or Federal agency which could provide funding after the start-up period.

Another lesson learned is that brokerage arrangements should be through an organization with established credibility within the companies served. Also, that centers should complement present and future associations among the membership.

In addition to the "success" of the MIT Polymer Program, we have learned some important lessons. One of the most important of these is that the sponsors of a "successful" center are more likely to come from divergent industries. Competition and anti-trust factors limit the degree of participation of firms manufacturing a

common product. Firms with established market success prefer to do all product-related research in house and wish to share only that research that is "pre-product" oriented. Such fundamental and basic research is also more suited to university and graduate student research and of broad interest to the U.S. science community.

In no case were any of the three experiments "failures" in terms of value to society. All three used the NSF funds for quality scientific research that fostered both new products and processes as well as new knowledge. As indicated above, all three increased our understanding of how to get the best leverage for Federal dollars in the support of private sector research and development.

Dr. ATKINSON. We refer to this as an experimental program, and we have here a report that summarizes the evaluation of the experimental program. I wouldn't want to say that the North Carolina center was not successful. I think it was quite successful. But I don't think the center has been as effective in drawing industrial support as we expected.

Senator SCHMITT. Well, we would like some information on that because, unfortunately, even scientists tend to call an experiment a success if there's been positive results, and they forget that an experiment can be a success if there have been negative results, because you learn from it. I think that's an unfortunate philosophical discipline we impose on our Ph. D. students, and we never let them write a thesis in which the results are negative.

I can't remember a single thesis I have seen or heard of that was allowed to be submitted with negative results. There had to be some kind of a positive return or it was called a positive return. Knowing something wouldn't work more often than not is more valuable in future planning than knowing that something does work. It's a little prejudice of mine against my fellow scientists, and I'm sure they all will sit and nod their heads and agree, but nevertheless, I don't expect the system to change very fast.

Now, a great deal of your effort, if I just peruse your testimony, Doctor, has been concentrated in major academic centers. That is in contrast to broader distribution of the agricltural efforts in the process which were distributed pretty much nationwide in the so-called land-grant college system.

Do you have a reason for that? There have been criticisms leveled at the NSF that you tend to go where you have gone before, rather than a broader distribution of your activities. Is that true in this innovation area?

Dr. ATKINSON. No. The answer is that we have had only three innovation—I think four—innovation centers and three university—industry research centers. I would like to see as many as 15 to 20 such centers run by the Foundation; the distribution of those over the country would make a great deal of sense. Certain universities in your region of the country would be ideal for this purpose.

Senator SCHMITT. What I'm getting at is that the first ones, as in so many cases of NSF programs, have gone into the same places that the first ones of other programs have gone into. Is that because they are more capable of writing proposals and being evaluated favorably than their peers?

Dr. ATKINSON. I don't think that's the case. I mean, MIT was one university, North Carolina State was another, and the innovation centers were at Oregon and Carnegie-Mellon. In the NSF act, as you know, is a requirement that we concern ourselves with geographic distribution, I don't think just looking at this sample would indicate our concern for geographic issues.

Senator SCHMITT. Well, let my question just say there is some concern that the distribution is not broad enough in your technical innovation program. Two of the three are in the Cambridge area. I've got a Harvard Ph. D. I have got great respect for that area, but I am somewhat concerned, particularly in this area of innovation, that whatever we do has got to be broadly distributed. We can't keep going back to the same well. The well is always very productive. I hope, within your evaluation system that you can look to the broader issue of how do we get a nationwide replenishment of the reservoir of innovation and not just an acceleration of what is already there.

Dr. ATKINSON. Senator Schmitt, I don't know if you know that this year we have initiated a program in which we have selected, on the basis of indicators, those eight States which we feel are at the bottom of the list of States in terms of their science and technology activities. We have now provided seed money for a limited program that will last about 5 to 7 years so that a community of outstanding leaders in industry and universities in each State can help identify basic and applied science opportunities in industry and in universities. We are providing seed money to get some of these activities off the ground with a clear view that we will be pulling out in 5 or 6 years. The States will have to begin to build bridges into other Federal agencies and elsewhere for subsequent funding.

We do take the charge of geographic distribution seriously. It is the basis for some outstanding centers of excellence in a few States, like California, Illinois, Massachusetts, and New York. For the size of the population in New Mexico, I think——

Senator SCHMITT. We have a unique situation in New Mexico with two of the national laboratories, Sandia and Los Alamos, a great deal of defense-related research, as well as a very fine agricultural research station at the New Mexico State University, so we feel very fortunate. Unfortunately, in New Mexico we still haven't caused all of this great science and technology to penetrate significantly into the broader population in terms of employment. We still are 45th in the Nation in terms of the salary average and have significantly high, or at least average unemployment. It hasn't quite happened yet, and that's something I hope your programs are looking at. How to get the transfer of the ideas into the local economy and not just the national economy, but the local economy?

Dr. ATKINSON. The science and education programs in the State of New Mexico are trying to increase the flow of people into the more scientific and technologically oriented world.

Senator SCHMITT. I understand that and I'm sympathetic with it, but we still have a brain drain. These people generally take jobs outside of New Mexico and they're not taking jobs in New Mexico and we still haven't got that one link in there that creates the jobs in the local area where the people are living and growing up and generally desire to stay, if they could have a job.

In that regard, it has been suggested that associated with these innovation centers of various kinds that there be an extension service possibly modeled after the Agriculture Extension Service.

Would you care to comment on that suggestion?

Dr. ATKINSON. I think that makes a great deal of sense. It could come in different ways. Some of our programs are intergovernmental science programs that foster this type of extension activity. And, again, I think a lot could be done there. But I would be worried about setting programs in concrete and building up a corps of people who see this——

Senator SCHMITT. Well, could you see an innovation agent situated in the counties of New Mexico or other States, as we now have agriculture extension agents?

Dr. ATKINSON. Let me think about that.

Senator SCHMITT. OK. We'd appreciate your comments.

I also would be curious to know your feelings about what I think is a principal reason for the success of the Agriculture Extension Service and the failure of other types of efforts along that line. The Agricultural Extension Service is a locally directed effort through the land-grant college, the extension agent and not a Washington-based direction. That is one of the problems that I foresee in the experimental energy extension service that's been developed. It is being directed by Washington rather than being directed at the local level, say, through the land grant or other university system.

People just don't deal directly with local problems when they have their direction—management direction from Washington.

Dr. ATKINSON. I feel very strongly about that; I agree totally. I would also want to add it is important for these centers to compete on a national basis in quality of work done.

Senator SCHMITT. There's no question that's what the land-grant colleges do. They compete against each other. But the movements of innovation in the Extension Service have been directed at the local level. It's created there, or if it comes there from other schools, it's distributed at the local level. And if you go around and find a Government program that has more popular support than the Agriculture Extension Service, I would like to know about it. It is universally recognized as a working, strong program, and the agents live and work in the area. They generally have grown up in that area and have become very, very effective parts of the agriculture community. Of course, they have other responsibilities too.

If S. 1250 was enacted into law, do you think it should contain some attempt to focus on types of innovative efforts? We talk about Agriculture, the NACA with an aeronautics focus, the national laboratories are innovation centers that focus on energy.

Do you think we ought to have those broad categories, or should we not have any restriction whatsoever?

Dr. ATKINSON. I'd probably have them focus much more tightly, like the NSF model. For example, when we think of the automobile industry, we might have three centers—research on combustion at the university, another on materials research related to the automobile industry, and another possibly to do research on design aspects. I guess I tend to prefer smaller centers somewhat more focused than a large center called of an automobile research center.

Senator SCHMITT. We have had some testimony at the last hearing to the contrary, and I imagine we will end up with some kind of a balanced view.

Do you think that the private sector support would be more forthcoming with more focused efforts, or do you think that would necessarily bear one way or the other?

Dr. ATKINSON. I can't really judge that, Senator Schmitt. You're as good a judge as I am.

I certainly think when it's clearly focused, when it identifies particular people in industry, and when there is a clearer commitment to the activities of that center, the people become advocates in the company for the activities of the center. But I can't judge.

Senator SCHMITT. Dr. Atkinson, I will submit to you for the record some questions having to do with the issue of commercialization of innovative processes or technologies that come out of a center of this kind, and also the question of patents—license policy which we would appreciate having for the record.

Thank you very much.

Dr. ATKINSON. Mr. Chairman, I appreciate the opportunity to be here. We in the NSF should be before your committee more often. It is always a pleasure when we are.

Senator SCHMITT. Don't say that very loudly.

Senator STEVENSON. Thank you, Dr. Atkinson.

[The statement follows:]

STATEMENT OF DR. RICHARD C. ATKINSON, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. Chairman and members of the subcommittee, I am pleased to take part in your consideration of S. 1250, the National Technology Innovation Act of 1979, and to discuss the National Science Foundation's experimental program designed to encourage a closer coupling of university and industry research efforts for innovative technologies and greater productivity.

The Foundation shares the Subcommittee's concern with figures showing a decline in the rate of productivity growth for the United States economy. Obviously, we must put the available tools to better use, and NSF suggests that a factor needing more attention now is the structure of basic and applied research efforts in this country. To that end, and in a small and experimental way, NSF is attempting to discover how university and industry scientists may work together in creating new scientific and technical knowledge.

For the past six years, NSF has supported experiments in several differing types of university-industry research cooperation. Since the Subcommittee is proposing in S. 1250 the development of improved linkages between the universities and industry in cooperative research, it may wish to draw upon NSF's experience with these experiments. The Foundation's goal has been to develop institutional mechanisms for coupling academic research capabilities to industrial needs and to fund joint university-industry projects to accelerate the production and use of new knowledge. Our Industry-University Cooperative Research Centers and our relatively new direct funding program for industry-university cooperative research projects are the mainstay of this effort.

Our University-Industry Cooperative Research Center experiment encourages research partnerships between industrial firms and university research laboratories to accelerate industrial innovation. This experiment consisted of three centers: the MIT Polymer Processing Center, the North Carolina State University Furniture R&D Applications Institute, and the New England Energy Development Systems Center. By far the most successful of the three is the Polymer Research Center at the Massachusetts Institute of Technology. There, a cross section of small, medium and large firms—including Eastman Kodak, General Motors Corporation, and Xerox Corporation—are participating in a variety of projects such as mathematical modeling of injection molding, improving the impact resistance of fiber-reinforced polyester, construction of new injection molds, mixing techniques for polymer materials, research on the friction and wear characteristic of polymers, and glass reinforcement. One measure of the Center's success is its rapid transition from federal to industrial support. Since its inception in 1973, industry contributions to the Center have risen from $50,000 year to more than $500,000 a year. Meanwhile, NSF

funding has declined; and for the past year, the industrial partners have paid the full cost. The Center is now self-sustaining.

While the other centers have not been as successful as the MIT center, they have provided us with available information about how to, and how not to, carry out such an experiment. The program as a whole has shown us that significant opportunities exist for expansion in a number of areas with long-term potential for improving technological innovation in U.S. industry. We are seriously considering an increase in the number of centers which might focus on such technologies as flexible materials, computer-assisted design, and others. In all cases the effort will be sharply focused on areas where science and technology can make important contributions by building on the University-Industry Cooperative Research Center concept.

The second major type of NSF activity involves support of cooperative research projects, a type of arrangement the Foundation began to highlight just last year. It has proved to be an attractive program in terms of the types of proposals received and funded. Support is provided for individual projects carried out jointly by academic and industrial researchers in many fields of science and engineering. The projects are investigator-initiated and focus on fundamental scientific questions. Individual proposals are first judged on the basis of scientific merit in comparison with proposals in the field of interest through the regular peer review process. If certain criteria are met, projects are partly funded by the Divisions whose fields of research are involved and partly funded from a special budget subactivity.

Major industrial firms such as DuPont, Ford, and Bell Laboratories are participating. Some smaller businesses are beginning to be drawn into the program. Academic institutions all across the Nation are involved, and not just the prominent research institutions. Let me give you some examples:

Bell Laboratories is working with Lehigh University on thermal convection in cavities (with applications to crystal growth).

Several computer firms are working with the California Institute of Technology on design of silicon structures (applicable to computer systems design).

Eastman Kodak and Clarkson College of Technology are investigating crystal formulation in surfactant solutions.

Artisan Industries is undertaking research with the University of Houston on the fundamental mechanics of a filtration process.

Now that the program is becoming known, the size of the response is exceeding our expectations and outpacing the funds that were budgeted. Quality proposals are being received in many fields, primarily engineering, chemistry, and materials research.

To complement these experiments I have described, the Foundation has undertaken several other initiatives. NSF's Small Business Innovation Program, for example, is attempting to increase the number of small business performers capable of conducting research and development for government and industry and of developing innovative products and services. Under Phase I of this program, small, high-technology businesses compete for six-month awards of up to $25,000 to conduct feasibility research on proposed innovations in specific topic areas selected by the Foundation. Phase I is designed to help the small business assess the feasibility of its innovative idea and to reduce the time and cost to the firm in preparing research proposals.

Successful firms in Phase I of this program become eligible to submit Phase II proposals to carry out the principal research effort for up to 24 months. Funding in the second phase of the program depends upon the quality of proposals and the firm's ability to obtain follow-on private funding from a third party to pursue development toward commercial use. In short, federal funding pays for research in these selected topic areas in Phases I and II, and private funding pays for subsequent work toward commercial use.

NSF also has been experimenting with Innovation Centers. These focus on small businesses and new business start up. They are located on university campuses and draw on the resource of the government, industry, and academia. They put new ideas to work and train young technologically-oriented entrepreneurs. These centers have fostered widespread interest in this country and abroad. An example of some of the advantages derived from the Innovation Centers come from the Center at the University of Utah. A new infinitely variable automatic transmission developed for bicycles, but which is now being adapted for many other applications such as power tools, motorcyles, snowmobiles and lawn mowers, was developed with assistance from the Center. The essence of this belt-driven transmission is a continuous automatic adjustment feature which gives the effect of an infinite range of gear ratios.

Interest for this type of center approach has been expressed in several quarters. The Canadian government, for example has authorized the establishment of NSF-

type innovation centers in two provinces; several may be established in Western European countries.

The Foundation also is concerned with the time consumed between the publication of research results and their use in the marketplace. We recently inaugurated a Technology Innovation Program (TIP) in an effort to shorten such time. A major project in this program builds upon research results in programmable automation conducted at the University of Massachusetts, the Stanford Research Institute, and the Charles Stark Draper Laboratory, Inc. This is a cost-shared project with the Westinghouse Corporation. It is an experimental to determine whether programmable automation can be applied to an automated assembly for batch manufacturing.

I should point out that NSF supports basic and applied research in many fields where the results are of interest to industry. You will notice, however, that in our programs for innovative technologies and greater productivity, we place special emphasis on arrangements that have three main characteristics: (1) they match university resources with the needs of industry in a specific area; (2) they generate new research opportunities for university and industry, and (3) in a fairly short time they become—or have promise of becoming—self-supporting and independent of federal support.

The use and acceptance of NSF findings encourages use to continue experimenting with the technological innovation process to stimulate university-industry cooperation. Because of this, it is extremely satisfying to be here to discuss the NSF's experiments with university-industry institutional arrangements as they apply to the particular legislative interests of this Subcommittee. The application of university talent and research to growth and productivity of industry—with the Federal Government serving as a catalytic agent—is to be commended.

Mr. Chairman, this concludes my statement. I will be please to answer any questions that you or other members of the Subcommittee may have.

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

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
*Washington, D.C., July 12, 1979.*

Dr. RICHARD ATKINSON,
*Director, National Science Foundation,*
*Washington, D.C.*

DEAR DR. ATKINSON: I wish to extend my appreciation for your most informative testimony on S. 1250 before the Science, Technology, and Space Subcommittee. After reviewing the testimony of all the witnesses during our June 27 hearing, I would greatly appreciate your responding to the following additional questions. Please address your reply to Mike Crisp of the Senate Committee on Commerce, Science, and Transportation, Minority Staff, 5102 Dirksen Senate Office Building, Washington, D.C. 20510. If your reply is received by July 31 there will be no difficulty including it in our hearing record.

1. Does the prospect of two companies, that are competitors within the same industry, contributing funds and personnel for a joint research project at one of the Centers for Industrial Technology present any potential antitrust questions? If antitrust problems are anticipated, what needs to be done to avoid these problems?

2. Does S. 1250 contain sufficient incentives to insure significant participation of industry in the Centers for Industrial Technology Programs? What are the most important incentives contained in S. 1250? Can you suggest any changes in S. 1250 what would increase the incentive for private sector participation?

3. The bill S. 1250 has a provision which would allow issuance of an exclusive patent license if industrial support or commercialization requires it. Who do you think should decide that an exclusive license is required? Are the patent provisions of S. 1250 appropriate for the Centers?

4. The bill S. 1250 discusses the commercialization of inventions that are developed at the Centers for Industrial Innovation. At what stage in the "commercialization" process should the Center step aside and let the private sector take the product the rest of the way to the market place?

5. The bill S. 1250 creates the Office of Industrial Technology within the Department of Commerce. This office will serve as the focus for innovative policy in the United States government. Do you feel that it would be appropriate for this office to perform the function of scrutinizing federal regulations and tax policies that are identified as serious impediments to innovation in the private sector? Can you suggest any changes in S. 1250 that would make the Office more effective in

combating burdensome regulations and inappropriate tax policies that are barriers to innovation?

Once again, I would like to thank you for taking the time to present testimony during our June 27 hearing on the National Technology Innovation Act.

Sincerely,

HARRISON H. SCHMITT, *U.S. Senator.*

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NATIONAL SCIENCE FOUNDATION,
*Washington, D.C., August 10, 1979.*

MR. MIKE CRISP,
*Minority Staff, Senate Committee on Commerce, Science, and Transportation, Washington, D.C.*

DEAR MR. CRISP: Thank you for your letter of July 12, 1979, regarding our testimony on S. 1250 and requesting responses to a series of questions.

QUESTION 1. ANTI-TRUST IMPLICATIONS

There are always potential anti-trust implications when two or more companies in the same industry interact. The question becomes more serious as the number of companies cooperating or their individual size or share in the market increases. However, under the conditions of our experiment with university-industry centers, the prospect of two companies that are competitors in the same industry raising serious anti-trust questions is low. First of all, each center, as part of our recommendations, would have companies representing various industries; in most cases, only one or two companies from an industry would be represented, and, usually, they would not be in competition with each other. Secondly, the National Science Foundation recommends that the university take the lead role and allow open access (on a fair and reasonable basis) to information generated at the center, that membership in center activities be open to all that can pay the appropriate fee, and that research results ultimately be published in the open literature. These actions further reduce the potential for anti-trust implications. In the final analysis, and, in order to put potential anti-trust problems to rest, it might be advantageous to receive opinions from the Justice Department on specific cases.

QUESTION 2. INCENTIVES

Incentives, in general, appear adequate in S. 1250. The most important incentives are found under Section 6(a)(1) and (b)(1)–(4) calling for participation of individuals from industry and universities in cooperative technology innovation activities. This could be improved upon by indicating that the research agenda should be developed jointly by the university and industry partners. Also highly important are the provisions under (c)(3) calling for the center to become self-sustaining, if feasible, and the provisions under (e)(1)–(7) concerning patents.

QUESTION 3. EXCLUSIVE LICENSES

The disposition of exclusive licenses should be decided by the center (university-industry partners), and, as such, the patent provisions in S. 1250 are similar to those successfully used in our experimental university-industry centers.

QUESTION 4. COMMERCIALIZATION

It is recommended that the centers be initially established with strong private sector involvement (as with our experimental centers); and if the research principles are developed jointly, one can expect a smooth flow from the center to the participating companies. Thus, the participants would have the option of determining how far to go in commercialization of any product or process. Transition from university to industry would also be improved by involving industrial scientists working at centers or center scientists working at industry.

QUESTION 5. TAX AND REGULATORY POLICIES

We have no findings on the above but feel that research and development centers should confine their direct actions to those outlined in the Bill, as shown in Section (b)(1)–(4). Any efforts concerning Federal regulations and tax policies should be confined to studies and fact finding in the technologies and industries involved in the center. This should be accomplished with participation of the appropriate Federal agencies.

A final suggestion, according to our findings, is that the activities listed under section 6(b)(1)–(4) are appropriate to two separate operational structures. Paragraphs (1) and (3) correspond to a major center that deals with existing business, mostly on the medium to large size, while paragraphs (2) and (4) are related to centers emphasizing emerging business, either new or on the small size. Our experiences indicate that these should be separately organized and directed but may be under the cognizance of an umbrella-type organization.

The above recommendations are based upon findings from our experimental university-industry centers and may require modifications for other types of centers. Please call upon us if you need additional information or comments on your proposed legislation.

Sincerely yours,

JACK T. SANDERSON,
*Assistant Director for Engineering and Applied Science.*

Senator SCHMITT. Mr. Chairman, is it my understanding that Dr. Baruch will not be here?

Senator STEVENSON. Not today. He will testify in the near future.

Senator SCHMITT. Are we awaiting the results of the President's domestic policy review?

Senator STEVENSON. That's part of it.

Senator SCHMITT. I hope that these domestic policy reviews do not become an inhibition to the administration to provide us with their advice and counsel on various areas. They certainly don't have to take a position, but there should be some things that they can say about the general issue and their experience, what they are studying, and various items of that nature.

Senator STEVENSON. Dr. Baruch isn't willing to appear here today, but I am hopeful his testimony will be more to the point.

Senator SCHMITT. Thank you. Mr. Chairman, we have run into the domestic policy reviews on other occasions, and I just hope that it is not becoming a way of life for the administration.

Senator STEVENSON. I share your hope and your anxiety, and I think we will both be pleasantly surprised when Dr. Baruch does appear.

Our next witness is Dr. Lewis Branscomb, vice president and chief scientist, IBM.

You are here voluntarily, no subpenas?

## STATEMENT OF DR. LEWIS M. BRANSCOMB, VICE PRESIDENT AND CHIEF SCIENTIST, INTERNATIONAL BUSINESS MACHINES CORP.

Dr. BRANSCOMB. Absolutely. Enthusiastically, sir. It is a subject I am deeply interested in.

With your permission, I have quite a short statement, and I would like to go through most of it.

Senator STEVENSON. We will enter your full statement.

Dr. BRANSCOMB. I am Lewis Branscomb. I am vice president and chief scientist of the IBM Corp., and president of the American Physical Society. I welcome this opportunity to speak with the committee about the encouragement of technological innovation in the United States and the contributions that could be made by the National Technology Innovation Act of 1979.

A lot of people think American industry has lost its technical capability and has abandoned research and development. Let me put the facts as they are.

It is the Government, not industry, which has exhibited the most uncertainty about its science and technology investments in recent years.

In 1980 private industry will fund approximately half of all the R. & D. in this country and will perform 72 percent of a total $57.3 billion national effort. The trends are positive and 1979 funds for industrial R. & D. will increase by about 15 percent above 1978 levels. They are predicted by the McGraw-Hill survey to rise another 37 percent in the next 3 years to 54.7 billion.

In 1962 industrial R. & D. investments were only half those of the Federal Government; in 1980 they are almost equal. In constant dollars, industry investments in R. & D. have moved steadily upward throughout that period, while Federal activities have only recently reversed a declining trend. This is hardly a picture of American industry going down the tubes.

Furthermore, while industrial R. & D. is heavily concentrated in high technology industries, such as electronics, computers, and communications, as one might expect, some of the most dramatic increases in R. & D. funding are emerging in industries such as iron and steel, stone, clay and glass, and machinery.

Thus, the conventional wisdom that older industries have lost their confidence in R. & D. is not a valid generalization. What we need are the facts, sector by sector. S. 1250 would permit that work to be done.

Nevertheless there is widespread concern about the state of American industrial innovation that one finds in the press and in industrial and scientific circules. It deserves examination. The concern arises from three sources:

First, technologically advanced competitors from Europe and Japan are successfully challenging American business on many fronts where American business has been accustomed to an unchallenged lead. Other countries have caught up with us in some areas.

Second, the chronic appearance of inflation, combined with low economic growth, cries out for a rapid increase in the rate of productivity growth and the creation of new jobs and new solutions to our national problems through innovation. We need to innovate more than ever before.

Third, both business and scientific communities share a sense of frustration and, I dare say, the Government community as well, that the scientific and business skills on which we pride ourselves as a Nation are not being mobilized as well as they might be to address our problems.

Indeed, the national debate about technology has concentrated too heavily on the problems that progress brings. The institutional mistrust that results undermines the opportunity to mobilize our native ingenuity to get the job done. We've been holding back innovation unnecessarily.

The role of Government is, of course, a central question. Many of the foreign companies challenging American industrial leadership have benefited from direct Government protection and support. Yet the U.S. Government action seems to have focused more on the redistribution of wealth than on its creation. It is time to start building on our strengths, and review the balance between incentive and restraint on innovative private action.

The Government's experience with the encouragement of scientific excellence in this country and its success in working with the aerospace industry to develop technology for the Government's own operations activities have been outstanding.

On the other hand, the Government's involvement in commercial industrial innovations has been a mixed bag at best.

Thus, it is not surprising that after a good many years of study of the Government's role with respect to commercial innovation, little coherent policy has emerged and a great deal of skepticism surrounds each new proposal for specific Government action.

Nevertheless, I believe congressional consideration of this aspect of Government policy is quite timely. The Technology Innovation Act is an interesting basis for this discussion.

There is a healthy skepticism about the efficacy of Government intervention into commercial activities today. Fiscal prudence is becoming a political asset. The economic cost of regulation to achieve social goals is beginning to be reckoned and the virtues of competition in a fair marketplace are gaining new respect.

There is, as a result, a good opportunity to consider ways that Government can improve the environment within which the private sector innovates.

There is increasing understanding that research and development activities do not by themselves cause innovation. They permit it if the economic and business climate is conducive.

President Carter, in his science and technology message to the Congress last March, emphasized the Government's role in basic research support and accepted the view that, "The Federal Government should provide both a climate that fosters innovation rather than * * * direct support of research and development with commercial potential."

The dominant factors governing industrial technology investments are those mentioned in section 2(6) of the bill which describe the business climate. Erratic interventions or changes in the course of Government policy, however well intended, are the greatest deterrent to industrial innovation because they escalate an already high risk associated with innovative activities for new business development.

In other words, confidence in the long-term future is the most essential single requirements for private investment in innovative development.

The President's domestic policy review of innovation, now complete and under review in the White House, should be expected to make a major contribution to the public discussion about the role of Government in this regard.

I hope the President will make this entire study available for public discussion and for review by this committee. There should be full debate and clear understanding about the two aspects of the Government role: first, improvement in the business climate for innovation and, second, support and encouragement of the kinds of scientific and technological activities upon which innovating enterprises can draw.

This bill, focused on the authorities of the Department of Commerce, deals largely with the second role. Thus, the name of the

bill is somewhat misleading; it deals with only the second half of the problem as I have defined it.

The philosophy embodied in S. 1250, in section 6(a)(2), correctly focuses on, "The development of a generic research based important for technological advance and innovative activity * * *" as the right way for Government expenditures to help business.

For 10 years, since I first served as Director of the National Bureau of Standards, I have urged that the best way for Government R. & D. investments to help industry is by investing in high quality scientific research of generic importance to industry, but not focused on narrow, proprietary objectives.

I am delighted to see this view reflected in this bill, and supported in the President's proposals for improving the scientific base for advances in automotive technology, announced May 18 last.

But there are two elements missing in S. 1250: A scientifically competent Government laboratory to set up and manage the centers, and active participation by industrial scientists in the setting up of goals and priorities.

The National Bureau of Standards should be given the first of these assignments, if this is in the Department of Commerce, and mixed industrial/university panels should be specified to set priorities and evaluate effectiveness of the centers.

Fortunately, the attitudes of faculty and students in our universities toward research cooperation with industry, have become much more positive in the last 5 years. This augurs well for the kinds of proposals envisioned in the statute.

It should be possible to choose specific projects that are both basic enough to interest the universities and pertinent to industrial needs to attract industrial participation. But if the effort focuses, as I believe it should, on generic, nonproprietary applied research, one must recognize that it is illusory to expect major, continuing funding from industry.

Nevertheless, the program should not be attempted without overt industry involvement, especially in selection of research areas, review of work quality and accomplishment, and loans of technical personnel. Perhaps specific project support could also be expected, building on a stable base of institutional support from Government.

But other patterns of university industry support are worth trying, too. For example, matching grants might be made available to universities for specific projects partially funded by a single company. Such direct partnership projects may be more attractive to both sides than the multilateral institutional proposal of S. 1250. But both patterns should be tried.

Let me now return to the environment for innovation. S. 1250 usefully calls for microeconomic fact gathering and policy analysis. It falls short of focusing on the responsibilities of the Secretary of Commerce to accept the responsibility for enhancing economic development based on industrial and technological strength in America.

This does not imply new programs of expenditure beyond those envisioned in S. 1250. I have already agreed that support of generic research, aimed at technologies important throughout industry, is the correct role for Government.

But it does mean that somewhere in Government there should be a focus of attention at Cabinet level on all the factors which, taken together, determine the innovative and productive vitality of our Nation's industry.

Why not take a more ambitious step with this legislation and assign this responsibility to the Secretary of Commerce so all the capabilities of the department will be focused on it?

In these brief comments, I do not have time to comment on the details of S. 1250. I am concerned that the patent provisions of 6(e) should permit negotiated terms for preferential rights by a participating company to patents arising from projects in which that company invested.

The absence of such rights may be a disincentive to industry participation in the program and thereby defeat the objective of the legislation. I am submitting for your consideration and the record a correction to section 6(e).

I don't understand why 7(c)(2) disallows payments for rental of space occupied by a center. And the provisions of 7(c)(3) are insufficiently safeguarded against governmental intrusion into commercial proprietary information not strictly relevant to the auditing responsibility of the Government for its funds.

Let me conclude by commending the committee for taking this initiative. I hope the administration soon comes forth with its own proposals, and releases for public discussion the domestic policy review on innovation.

It is time we Americans began the construction of harmonious, constructive relationship between Government, the private sector, and our universities. In the field of innovation promotion we may want to start modestly and carefully, but we should start.

Thank you.

[The attachment follows:]

SUGGESTED ADDITIONS TO S. 1250, SECTION 6(e)

(8) When the invention is made or conceived by an individual participating in cooperative industry-university basic and applied research effort under auspices of the Center, such individual or party to whom the individual has agreed in writing to assign the invention shall have an irrevocable, royalty-free right to practice the invention, or have the invention practices on its behalf, with the right to grant sublicenses of the same scope; and

(9) Any organization participating in cooperative industry-university basic and applied research effort under auspices of the Center during the time that the invention was conceived or made, shall have an irrevocable, royalty-free right to practice the invention, or have the invention practiced on its behalf, with the right to grant sublicenses of the same scope to subsidiaries and other affiliates within the corporate structure of the organization.

Senator STEVENSON. Thank you, sir.

How do you distinguish between basic scientific research, generic applied research, and commercially oriented research? Would you make those distinctions, please?

Dr. BRANSCOMB. Well, it is difficult to make the distinction—it is similar to the problem of distinguishing between basic and applied research; but I believe the distinction can be made.

An easy one to distinguish is the proprietary type of research. This is a technical activity whose immediate economic value strongly suggests the wisdom of maintaining that information within the institution that will do the innovation. Proprietary re-

search also has been conducted with the specific intent of exploiting it economically, so there will be a return to the economy from that investment.

The other two categories of research I distinguish in my mind by whether the investing institution has a specific need for the information in mind. I will speak to that in a moment.

Now let me distinguish the basic research side by suggesting that the principal value of basic research is the knowledge gained in a sphere of activity without specific reference to any economic attributes to that knowledge. It will usually turn out that those who, even in industry, are investing in that kind of science will find it to their own advantage to publish it and share it widely with the scientific community, both for criticism and to stimulate other work.

And of course, the value of basic research is very general. That will also be true in the more applied area, where one may also find it advantageous to have that published and widely available. But the applied problems are of value for the solutions to known technological problems that they provide. One can perhaps best describe it by examples. There is a great deal of work in metallurgy, in metrology, in instrumentation, in polymer science and technology, in combustion chemistry, and in all the fields of engineering which have this characteristic.

I think if you were to examine, program by program, the emphasis of the majority of the activities of the National Science Foundation and compare them with the technical activities of the Bureau of Standards, you would see that difference in philosophy reflected. You would find the interest of industry scientists and engineers in the kind of work done at the Bureau of Standards relatively more pertinent to their immediate concerns than you will the more ranging scientific activities of the Science Foundation.

The exception to that would be in those industries that do a great deal of science as well. But the committee must remember, very few companies in this country do very much science. Only a large enterprise can afford to invest in science; most of them are engaged in engineering activities, much of it very innovative.

The innovation process is a process of bringing those ideas, mostly applied, to commercial exploitation.

Senator STEVENSON. Well, in response to what Senator Schmitt said there earlier, I didn't mean to suggest the substition of the Government for industry in determining research priorities. But the subject does perplex me, because I don't think our history is of much advantage to us, nor have any of the resources, such as market preference at the moment, which has very little to do with the future in this radically changing world.

I suppose there is some risk in all of this in defining what is the fallibility of the Government with all of those industries in producing things like the Concorde. Of course, I sense that other countries are profiting from their very different experiences and are developing new models which involve the strength of government and industry in a cooperative effort to identify proprietary objectives. The French have learned from their experience with the Concorde, and maybe at least subconsciously they are recognizing that gov-

ernments in this world create the proprietary objectives. They create markets.

We sat here not very long ago deregulating the airline industry, recognizing to ourselves that we were creating a market for a whole new generation of aircraft. The industry never recognized that. And now it is Brazil that is moving in and the Russians to supply the market here and in the world for new aircraft—a new generation of aircraft while we are making DC-10's and airplanes for general aviation.

We cited the automobile industry not very long ago, where we were busy making Cadillacs while the world went to smaller, more energy efficient automobiles; and the Government—Congress moved in with fuel efficiency standards, and industry began to respond in a way that serves its own interests.

You mentioned aircraft, the benefits of the aerospace industry, with Government support. That was kind of accident. What I am getting at is, is it by accident the United States can help support or stimulate an aerospace industry which becomes dominant in world markets? And, incidentally, also the computer industry? Shouldn't we be at least considering what we might do by calculation by trying to combine the resources of Government and industry with a view to identify those proprietary objectives and support them?

Dr. BRANSCOMB. I believe that strategy for Government, industry and universities to work together should derive from as much of a national consensus as we Americans can put together on where our economic strengths and needs lie. And that's why I think the first element of your bill, which charges the Department of Commerce with analyzing where these strengths are, in both economic and technological terms, is something that is very badly needed.

I don't think it would be terribly difficult to arrive at a consensus on where our major economic strengths are and major national needs are.

The issue then becomes: How does the Government foster progress in these areas? In my view, that takes three forms. First, the Government can foster markets for the kinds of technical and economic solutions that we need.

This legislation doesn't speak to specific kinds of issues. But speaking for myself, I think the Congress is wise in developing a demand/pull strategy for oil shale and new forms of fossil fuels.

One can anticipate future needs, and the Government can provide a market stimulus for new solutions under economically realistic terms.

So, I am not opposed to that notion.

I would indeed note that it is very important for the Government to be a sophisticated consumer. And there are fields of technology in which the Government is not a sophisticated consumer. It lags far behind industry in its technical practice and, therefore, it does not exert a driving force on industry for better performance.

But the bill deals, as I read it, quite properly with the broad question of how we provide innovative stimulus to our economy as a whole, without reference to any specific field, like health or energy or transportation, that might be of national concern; and it seeks to find a way to foster going there by a broad mechanism. It doesn't require the specific mission oriented activities.

We do need solutions along those lines, and thus we come to the second and third forms. The second form is to improve the environment within which private investment will draw on the available technical sinews of the country to solve problems. And that has to do really with business climate for risk taking with private money.

That is the problem which I hope the President's study addresses front and center. It is clearly a governmentwide problem. The Department of Commerce is certainly not the only, although maybe the principal, agency which determines the business environment for innovation. And my testimony is a plea to insure that national focus stays on that issue.

The third form of Government involvement encouages industry to have its R. & D. more productive and its innovation opportunities fostered by having a richer bed of technology and ideas and skills available to draw upon.

That is what this legislation is about, as I read it: the interface of university and industry activity. I want to be on record as favoring the notion that that is worth trying; that it should be tried in the context not only of NSF, where I applaud what they are trying to do for science, but it should also be attempted at the level of engineering and applied research of a character that industry people will be willing to commit their money and, more important than that, their most talented people to that cooperative activity with the universities.

And if indeed that is to be a success, then I think the fields of technical exploration that are chosen and the way of setting the detailed choices of projects must derive from a full partnership of industry experts and university experts, with government participating.

I would then see three levels of priority setting. At the top level, the consensus says let's invest in our strength and let's focus our strength toward major national priorities. That comes out of the microeconomic analysis plus the national political consensus.

The second level would be the choice of what kinds of centers to try to establish, which derives from the first, and from some kind of an advisory boards or panels of the sort that are envisioned in the last part of the act, but which should be specifically designated as strategy setting and evaluating for the centers.

The third level is that the detail in the center itself, hopefully priorities, will be set there as the participants vote with their feet and their wallets.

I could imagine that indeed the centers must receive some basic institutional funding from Government. It is entirely appropriate. But they should also receive from industry. That could be a matching formula basis, or it could simply be voluntary for specific projects.

That is also an important area of strategy setting, because if the industry funding is not there, then the centers direction may be wrong. I agree with Dr. Atkinson, a center helping an industry which will not invest in the center, is a questionable enterprise.

Senator STEVENSON. Don't you think that any process which does identify a priority for innovation is likely in this day and age to identify some industry that will not commit its resources?

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Let me cite an example. I am concerned that the climate will never again be as favorable as it was in the 1960's, for a lot of reasons which we need not go into. There are, of course, forces that are just beyond our control and there are climates in the world that existed in the 1960's. It is becoming a highly competitive business just between governments just to be able to obtain a favorable climate; an example of genetic engineering, in which the company identified the need for the opportunity to move to Switzerland.

But there are magnitudes involved, too, that sometimes divide the resources of the private sector, which is now faced with—always faced with a lot of competing demands upon the private sector opportunities, especially with interest rates up around 12 percent.

I don't know how many studies have been conducted on materials policy. They go back to—way back. But I think I may be overgeneralizing; but the conclusions of these various studies have come true, and the priority is not just proprietary or commercial.

There are national security implications which would seem to me to demand some action, like energy. We can put a lot of money into competitive tools and maybe are compelled to do so because the incentives of industry are to make a profit. And in this world, tight energy supplies help profit and incentives to produce the production of fuel, no matter what the strategic implications are.

I don't know what the reason is with respect to material, but we do know we are dependent on many undependable foreign sources of raw materials, just as we are for fuel, and yet the investment hasn't been made.

The deposits of new materials have long been developed and certainly we are not lacking studies or predictions. In those instances I suspect these are just examples.

Doesn't the Government have to involve itself in a way it has not in the past in developing the technology which includes case materials, commercial products, and proprietary information, figuring out how to parcel it out to industry? I'm not suggesting actual production.

In other words, does this bill go anywhere near far enough? Does it address itself to the ad hoc situation which materials may be necessary and a sure investment in R. & D.?

Dr. BRANSCOMB. I think there might be circumstances in which the Government is justified in going well beyond generic support and improving the business environment and taking an active role in the creation of industrial capability, which is needed more quickly than private incentive will provide.

I think those examples are few and far between. We are all fond of citing the synthetic rubber efforts in World War II and the optical glass effort in World War I. In both cases the Bureau of Standards had a major role in achieving that effort.

I believe that many people are tempted to try to go too far in this direction without examining intermediate opportunities which have greater potential, in my view.

I would like to make a distinction between whether or not the industry invests a major part of the capital available to it in new

technology which is not, with any confidence, predictably economically competitive with other alternatives.

If you want to use the fuel example, a company may have an opportunity to invest in marginal exploration or tertiary recovery of existing oil fields, or it may have a synthetic fuels alternative. And it may well be that industry is not investing in synthetic fuels at a high enough level because their economic calculation says that the equivalent price is not likely to be competitive within the time frame they have to look at for their investment. And if the price of oil goes up, it raises up the price of synthetic fuel and they can't make a business case.

In that situation, I think the Government should look very hard at the appropriate level of risk that the country faces for not having been involved.

I personally think that's a very high level of risk, and the Government should then consider taking appropriate action.

Now, at the same time, if you ask what is that action and how do you carry it out, I would insist that even though the industry may not be investing most of its money in solving the problem, a substantial part of its money may be tied up in major investments of a near term value. There may be no question among the industry's technical experts that, indeed, the best next alternative is synthetic fuels.

So, if the Government accepts the role of sharing in the risk, and decides to go ahead and invest national assets in those activities before they would be given the first priority by industry, it does not follow that one shouldn't use industry to do the technical work. The industry experts who understand these technologies and their economic evaluations should be involved, cooperating with whatever Government-sponsored work in universities or national laboratories goes on.

It's in that spirit that I believe that these more generic kinds of approaches in this bill could, indeed, involve an appropriate investment of Government funds in generic technology that all of industry will equally benefit from.

But there should be a direct participation in those activities by the experienced engineers and scientists and technical people from the companies, on a voluntary basis, so their technical judgments are brought to bear. In this way we should be able to understand why companies invest the way they do.

I don't think there's any great mystery about it. Their job is to be economically efficient and to serve their customers at the lowest price they can in a competitive world, and they will indeed invest in whatever solution most immediately meets that market need. They will invest in those solutions instead of more expensive ones, even though they know that sooner or later, the more expensive ones may be required.

Senator STEVENSON. Well, they'll do it if they have the incentives and the information and resources. They may not have any.

Dr. BRANSCOMB. But in any case, I do believe that is those exceptional situations are where the public's money should be used to help defray the risk, that is when the company management doesn't believe that their stockholders should have to bear that risk—then in these specific cases they need to be debated and

authorized, and I would assume that that goes on and is going on today in those agencies of Government that have those missions.

It's not easy to deal with those kinds of things, and not even wise, in my opinion, on a generic basis at this point, particularly since in some recent cases the Government has tried to do this and hasn't done very well.

I cite to you, with all due respect, the nuclear power industry. The commercial power industry was fostered by the Atomic Energy Commission on precisely this basis. This was a high risk investment and it required Government participation to accelerate it, and to hand it over to the private sector.

And some of the academic studies of that history that I have seen suggests that more independent industrial risk taking earlier would have worked better than what we have today.

Senator STEVENSON. Thank you.

Senator Schmitt?

Senator SCHMITT. Would it be fair to distill some of what has transpired between you and the chairman in the following way: No. 1, at the present time and in, the foreseeable future, a very high economic risk in research and development and pure science, which is basically curiosity, is going to be funded by Government. Hopefully, there will also be a significant participation of private resources through the university or private foundation research community.

No. 2, the lower economic risk applied research should be, for the foreseeable future, the function of industry responding to consensus standards set by Government. The transition between No. 1 and No. 2 is really what we're discussing or focusing on today because those other two are happening at the present time?

We could argue about the rate at which they're happening and the emphasis put on the way in which they're happening. In that transition, we have kind of a cooperative development that might result in a synthetic fuel technology, and which really was historically part of the nuclear power technology development. In the latter case, I would agree that the cooperative development was not done well technically or managerially. The innovation center concept provides a mechanism by which, through multichannel links, the technologies developed under high risk research and development programs and through pure science can flow more readily to the low risk application of technology.

Is that a reasonable distillation?

Dr. BRANSCOMB. I have two problems with that summary, Senator.

The first is your use of the words "basic research." I believe it is vital that this country—the Government— must sustain the leading edge of basic science. There's no other possible source of funding.

Senator SCHMITT. I did not intend to say that.

Dr. BRANSCOMB. But I want to give very strong encouragement and reinforcement to the language of this bill when it refers to a generic research of technological importance to industry.

We can agree perhaps to use the words "basic research" to cover that in the sense that this is a published work which universities have an interest in participating in.

But I really believe that, in the government's investment in science and the generic, we have short-changed private industry in not putting enough emphasis on these areas of published university-involved research, which are of direct use to companies.

We have emphasized the things—the leading edge of science that the universities and their arts and science departments, if you like, have the most interest in.

We have shortchanged the knowledge and support that can be given to R. & D. activity in industry.

And let me just mention one thing that's not on the record yet this morning that just beautifully exemplifies that: The Weinberg report of the President's science advisory committee in 1958. We are at the 21st anniversary of that report, which recommended that it would be enormously useful to industry and to anybody solving problems in this country if there were an organized and well structured, evaluative scientific and technical information service and knowledge basis available in the country.

The Bureau of Standards established a national standards and data reference system, and it meets that need to some degree. But it has a trivial level of coverage of the practical engineering data that are used by the hundreds of thousands of middle sized and small, and sometimes large companies out there that do not have corporate research laboratories and don't engage in high science.

It's the shirt-sleeve engineering technology base that needs to be made available in this country. And the way I read this bill, it was an encouragement to the Department of Commerce to put some real money behind activities that go on outside the Bureau of Standards in universities and centers to provide that base.

That's part No. 1. I just wanted to emphasize very strongly that extension because with all due respect to Dr. Atkinson, that is not the area that NSF has given any significant emphasis to in its entire history.

Senator SCHMITT. Just to illustrate what you are thinking of, are you thinking of the kind of thing that was done through the NACA?

Dr. BRANSCOMB. Yes. That would be a good example. And I would even harken back to my NBS days and remind you that that came from the NBS originally.

The second problem I see with your summary has to do with the other side of the coin: The Government's participation in the innovative process.

I believe it is very appropriate that in the key technical areas we discussed—synthetic fuels as an example—the Government should participate in forcing the technology, and even the invention process.

Innovation is a set of events that takes ideas and inventions and moves them into commercial exploitation.

Senator SCHMITT. Could we just generalize and say exploitation, and not necessarily all exploitation will end up making a profit or being commercial?

Dr. BRANSCOMB. Yes. Innovation would be bringing the results of ideas and inventions to the end user. In a socialist society, that's done by the government and not by industry.

Senator SCHMITT. Well, there are examples such as medical science in our society where the product of innovation does not bring a profit.

Dr. BRANSCOMB. I don't believe I mentioned the word "profit."

Senator SCHMITT. You said "commercial."

Dr. BRANSCROMB. I said "commercial". Unquestionably, many companies commercialize without making a profit.

Senator SCHMITT. Many institutions commercialize again without making a profit.

Dr. BRANSCOMB. Right. And so I would make an important distinction between the innovation and technology work. And I really don't believe it is reasonable to expect that centers that are located at universities that involve Government funding and participation by university scientists, and perhaps industry scientists alone, will be in a position to make the kinds of economic tests and market evaluations and will be able to generate even the technical plans for parts logistics, for field maintenance, customer service, and for all the other things that go into bringing the results to the end user.

Therefore, I am much more attracted to these areas where there is a specific innovation we know we need that we want to see brought to the American people.

In those cases, I am much more inclined to the view that fixing the business climate for solving the problem is not enough, and supporting those industries with the knowledge base is not enough.

In any event, the right answer has to be for the Government to try to create an artificial market and the notion being discussed in the synthetic fuels area, in which you define the technology, let us say, coal conversion to liquid fuels, and you set a specific for what that product is to be, and you take the competitive bids from companies, stating a price that they will deliver 50,000 barrels a day of that product in 19 whatever it is, and then you pick the best qualified bidder.

And the Government agrees to purchase that product at the contracted price.

That to me is an appropriate next generation technique which I believe in the energy field we probably need today, but probably not in many fields.

Senator SCHMITT. We have to be very careful about setting these specifics, though. The area of technology is going to be different. But I think one of the major failures that we can point to now with 20–20 hindsight in the nuclear power industry was that we went into a taxpayer-sponsored intensive and highly successful reactor development program, and we left the basic specification of the powerplant we put around those reactors to be determined by a regulated economically constrained power industry.

And I think, in fairness to that industry, they probably did about, the best overall job that could be done.

There are some things I would argue that they shouldn't have done, and maybe were careless about. But nevertheless, the constraints were very different in the development of the pipes and the valves and the electronic controls and the operating procedures and so forth that surround the reactor as compared to the constraints that the reactor development underwent.

And I think it's very clear that these powerplant failures—Three Mile Island and many others—have been powerplant failures and not reactor failures. It took a lot of work at Three Mile Island to get a reactor damaged, and we have to remember that.

Dr. BRANSCOMB. I think that's absolutely right.

Senator SCHMITT. And we learned from that lesson as we move to new nuclear technology and others. That's an aside.

Let me sort of follow up on some of the things that you have said. The Office of Industrial Technology, which is established by S. 1250, would be the focus for the development of innovation policy recommendations.

Do you think that it also should be the focus for scrutinizing and recommending changes in Federal regulations and tax policies as they impede the innovation process?

Dr. BRANSCOMB. I think the responsibility ought to be quite broad to examine the strengths and weaknesses in our industrial economy, to evaluate the effect—positive and negative—of Government policy on these strengths and weaknesses and to take the lead within the Government in trying to improve in whatever directions are appropriate, the total impact of government policy on the innovative process.

With regard to its location in the department, my reference would be to elevate that responsibility from a new office in the department and put it squarely on the shoulders of the Secretary and make it clear that that's really what the Department of Commerce is.

It's a department of commerce, trade, and industry and technology, and that ought to be the whole view of the Department. And the Secretary should use all of the tools of the Department, as appropriate, to do that job.

My reservation about the Bureau of Standards was simply that for centers which involve research activities, you need skilled technical professionals responsible for the Government's management and overview. I don't believe that we will easily be able to reproduce a new agency within the Commerce Department at the levels of experience that have existed for years in the Bureau of Standards.

Senator SCHMITT. What about the possibility of elevating the Director of the Bureau of Standards to an assistant secretary level, or something comparable?

Dr. BRANSCOMB. I think that's entirely possible. I'm really trying to emphasize the notion that when we look at the two halves of this problem—the economic and the environment half and the technology half—we appreciate that the Department of Commerce has, in my view, for too long lived with two cultures—the economic analysis with great emotion on one side, and the technology and environmental on the other.

And there's a real need to see those drawn together at the Secretary level and then redistribute the responsibilities appropriately.

The Assistant Secretary Baruch and his predecessors have tried very hard to cover both sides of that issue, and they have gotten secretarial support very often for trying to do the business environment and innovation part of the job.

And I really believe that it's hard to do that job on an assistant secretary level. That should be the focus of the whole department.

Senator SCHMITT. Finally, Dr. Branscomb, we will have a few questions that we would submit to the record on more technical issues. But you mentioned in your testimony, too, that 72 percent of the total of $57.3 billion national effort in R. & D. was performed by the private sector.

And presumably, you mean it was funded by the private sector?

Dr. BRANSCOMB. No, sir. Seventy-two percent is performed. Half is funded by the private sector.

Senator SCHMITT. Of that half that's funded, we have had testimony in other circumstances—that a vast majority of that is very short term and that its focus and it's in large part the consequence of regulation and standards set by the Federal Government rather than real innovation or imagination by the private sector itself.

Is that true?

Dr. BRANSCOMB. First of all, in a typical company, somewhere between 90 percent and 95 percent of their R. & D. is invested in the development of products which the company specifically plans to manufacture and sell on a planned timetable. And there are industries in which this development cycle for new products is as long as 5 to 7 years. I suppose in aircraft that may be so. But for the very biggest computers, it's 4 or 5 years.

In most businesses, they can't afford such a long development cycle. You have to predict it will be at a given level 5 years out, and then commitment of your resources, your people, your capital and your plants in a business. That's a risky business.

So most businesses, indeed, are forced by the economic facts of life to compete on the basis of a development cycle of a few years—3 or 4 years—and that's the kind of short term you suffer.

I do think it's very important that we distinguish innovative and noninnovative activities as opposed to new long-range and short-range business activities. Many inventions, perhaps most inventions, do not involve any new science. They involve bright ideas about how to combine the materials and devices and things that are available today to do a job that hasn't been done before.

That does not necessarily take a long development cycle. It may indeed be very short.

I think probably the most important innovation made in IBM in recent years, is the erase feature on our typewriters, at least in terms of value to the user. Compared to the size of the effort, it was a modest contribution, at a modest cost, but very important to typewriters.

Senator SCHMITT. Very important to the typist.

Dr. BRANSCOMB. To the typist. I accept your correction. You're absolutely right.

Therefore, the long range aspect of innovation comes in when we're looking at specific innovations that do require science, for example in the energy field. It's hard to invent out of your mind a solution to energy sources which doesn't require some new science or at least some new engineering, although in the conservation side I would submit there's a lot of opportunities for greater efficiency just by clever ideas, quickly implemented.

Senator SCHMITT. Thank you.

Senator STEVENSON. One more question, Dr. Branscomb. In these centers, do you see a role for intercorporate cooperation in the development of generic technology available to all; and if so, would it be impeded by antitrust laws; and is it impeded today by antitrust laws?

Dr. BRANSCOMB. I'm not a lawyer and I won't attempt to interpret the antitrust laws. But it's clear that, at least at modest levels, that kind of multiple company participation on the university campus on a university-sponsored activity is quite workable, and indeed, works right now. In most cases, these involve modest efforts in terms of numbers of people involved compared to the size of the companies' economic activity.

I would just cite as an example a laboratory at the California Institute of Technology in the computer-related field. Their computer department invited companies to send one technical expert each to spend a year and work with Cal Tech on a rather broad project. All the participants are obligated to publish the work that is done there and the people there are specialists in competing companies.

They themselves are not competing or involved in marketing, and they don't discuss prices of the product. So long as the participants, are bona fide scientists and engineers with serious intent to participate together in a publicly visible and available activity and no company is forbidden from participation, there's no exclusivity so that attached to it, then I think there's really no barrier to this kind of activity of which I'm aware.

But that's not a legal opinion; that's an opinion from observing what seems to work.

Senator STEVENSON. I thank you, sir. You have been very helpful to us. We might have some more questions to submit, as Senator Schmitt mentioned.

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

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
*Washington, D.C., July 9, 1979.*

Dr. LEWIS M. BRANSCOMB,
*Vice President and Chief Scientist, IBM Corp.,*
*Armonk, N.Y.*

DEAR DR. BRANSCOMB: I wish to extend my appreciation for your most informative testimony on S. 1250 before the Science, Technology, and Space Subcommittee. After reviewing the testimony of all the witnesses during our June 27 hearing, I would greatly appreciate your responding to the following additional questions. Please address your reply to Mike Crisp of the Senate Committee on Commerce, Science, and Transportation Minority Staff, 5102 DSOB, Washington, D.C. 20510. If your reply is received by July 31, there will be no difficulty including it in our hearing record.

1. Does the prospect of two companies, that are competitors within the same industry, contributing funds and personnel for a joint research project at one of the Centers for Industrial Technology present any potential antitrust questions? If antitrust problems are anticipated, what needs to be done to avoid these problems?

2. Does S. 1250 contain sufficient incentives to insure significant participation of industry in the Centers for Industrial Technology Programs? What are the most important incentives contained in S. 1250? Can you suggest any changes in S. 1250 that would increase the incentive or private sector participation?

3. The bill S. 1250 has a provision which would allow insurance of an exclusive patent license if industrial support or commercialization requires it. Who do you think should decide that an exclusive license is required? Are the patent provisions of S. 1250 appropriate for the Centers?

4. The bill S. 1250 discusses the commercialization of inventions that are developed at the Centers for Industrial Innovation. At what stage in the "commericalization" process should the Center step aside and let the private sector take the product the rest of the way to the market place?

5. The bill S. 1250 creates the Office of Industrial Technology within the Department of Commerce. This office will serve as the focus for innovation policy in the United States government. Do you feel that it would be appropriate for this office to perform the function of scrutinizing Federal regulations and tax policies that are identified as serious impediments to innovation in the private sector? Can you suggest any changes in S. 1250 that would make the Office more effective in combating burdensome regulations and inappropriate tax policies that are barriers to innovation?

Once again, I would like to thank you for taking the time to present testimony during our June 21 hearing on the National Technology Innovation Act.

Sincerely,

HARRISON H. SCHMITT, *U.S. Senator.*

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INTERNATIONAL BUSINESS MACHINES CORP.,
*Armonk, N.Y., August 23, 1979.*

Hon. HARRISON H. SCHMITT,
*Russell Senate Office Building,*
*Washington, D.C.*

DEAR SENATOR SCHMITT: In your letter to me of July 9, 1979, you requested my response to some additional questions relating to S. 1250. I appreciate this opportunity to address these issues, and to reiterate some points in my testimony before the Subcommittee on June 27, 1979. I will address your questions in sequence.

1. Does the prospect of two companies, that are competitors within the same industry, contributing funds and personnel for a joint research project at one of the Centers for Industrial Technology present any potential antitrust questions? If antitrust problems are anticipated, what needs to be done to avoid these problems?

I understand that whether there is an antitrust exposure if two competitors engage in a joint research project depends upon many factors, including: (1) The market in which they compete and the structure of that market; (2) the position of each competitor in that market; (3) the relative strength of other competitors in that market; and (4) the competitive advantage derived from the research. If in a particular case the competitors could be viewed as combining to monopolize or restrain trade, the fact that their joint research project was carried on at a Center for Industrial Technology would not insulate them from this exposure. The exposure could usually be minimized, however, if any invention resulting from the joint research project were made available immediately to participating organizations on a royalty-free basis, and to any other organization upon request for a reasonable license fee. The amendment to the patent provision which I propose in the answer to question 3 would provide for this.

2. Does S. 1250 contain sufficient incentives to ensure significant participation of industry in the Centers for Industrial Technology Programs? What are the most important incentives contained in S. 1250? Can you suggest any changes in S. 1250 that would increase the incentive for private sector participation?

I believe that, as a general rule, an industrial organization will prefer to manage its resources by carrying out research and development in its own laboratories. An industrial organization should have an incentive to participate in joint work, however, if it believes that the potential benefits warrant an exception. Such an exception would usually require that the work be relevant and of exceptionally high quality, that the organization have a right to use any developments, and that the organization's contributions be supplemented through the use of funding by other organizations, including the government's tax revenues, where appropriate. Of these considerations, quality is key: only if the Center does truly outstanding research and development will significant participation be obtained. The organization's right to use any developments can be achieved through satisfactory patent provisions discussed below. In terms of the government's participation, the government's use of tax revenues could be tied to industrial participation by a matching program.

3. The bill S. 1250 has a provision which would allow issuance of an exclusive patent license if industrial support or commercialization requires it. Who do you think should decide that an exclusive license is required? Are the patent provisions of S. 1250 appropriate for the Centers?

An exclusive patent license is generally inconsistent with the antitrust exposure associated with joint research projects. I have have previously testified that the patent provisions of S. 1250 should provide to a participating company "freedom of action" rights to patents arising from projects which that company invested. Attached is a proposed amendment to section 6(e) of the bill that not only provides for such "freedom of action" rights for pariticipating companies but minimizes the antitrust exposures as well.

This amendment protects the right of a participating company to benefit from its own investment through an immediate, royalty-free right to practice inventions. As I mentioned before, without such protection, private sector participation may be discouraged.

4. The bill S. 1250 discusses the commercialization of inventions that are developed at the Centers for Industrial Innovation. At what stage in the "commercialization" process should the Center step aside and let the private sector take the product the rest of the way to the market place?

I feel that determining rules for "stepping aside" is not an appropriate matter for legislation or regulation but is instead a management issue. The management of the Center should develop these criteria on a case by case basis after consulting with its industry participants and it government contact.

The Centers should carry out research of generic importance to industry and let individual concerns do the necessary follow-on proprietary work. However, the ultimate objective of the Office of Industrial Technology is to achieve commercialization. As an example, we in IBM encourage the research groups to go to considerable lengths to convince product groups that a new development should be commericalized. To assure an appropriate balance, you might consider having a panel of industrial experts preiodically review the success of the Centers in meeting their objective.

5. The bill S. 1250 creates the Office of Industrial Technology within the Department of Commerce. This office will serve as the focus for innovation policy in the United States government. Do you feel that it would be appropriate for this office to perform the function of scrutinizing Federal regulations and tax policies that are identified as serious impediments to innovation in the private sector? Can you suggest any changes in S. 1250 that would make the Office more effective in combating burdensome regulations and inappropriate tax policies that are barriers to innovation?

I have testified that the legislation should require the Secretary of Commerce to examine all the factors which, taken together, determine the innovative and productive vitality of our nation's industry. This would include a responsibility to examine the effect of regulation and tax policy and to propose needed changes.

Thank you for this opportunity to help you develop an effective approach for enhancing this country's innovative capability.

Sincerely,

LEWIS M. BRANSCOMB,
*Vice President and Chief Scientist.*

Attachment.

ATTACHMENT

Additions to S. 1250, Section 6(e):

When the invention is made or conceived by an individual participating in cooperate industry-university basic and applied research effort under auspices of the Center, such individual, or party to whom the individual has agreed in writing to assign the invention, shall have an irrevocable, royalty-free right to practice the invention, or have the invention practiced on its behalf, with the right to grant sublicenses of the same scope; and

* * * any organization participating in cooperative industry-university basic and applied research effort under auspices of the Center during the time that the invention was conceived or made shall have an irrevocable, royalty-free right to practice the invention, or have the invention practiced on its behalf, with the right to grant sublicenses of the same scope to subsidiaries and other affiliates within the corporate structure of the organization. Any other individual or organization shall, for a reasonable fee, have the right to practice the invention or have the invention practiced on its behalf.

Senator STEVENSON. Our next witnesses are: Prof. Dwight Baumann, Center for Entrepreneurial Development, Carnegie-Mellon University; Dr. David Morrison, executive vice president and director of the IIT Research Institute; Prof. Nam Suh, Department of Mechanical Engineering, Massachusetts Institute of Tech-

nology; and Dr. Gerald G. Udell, director and associate professor, Innovation Center, College of Business Administration, University of Oregon.

And I will invite all of these gentlemen to come forward as one panel, if you would. We have received all the statements and we will proceed with all the statements and return to the full panel with some questions. And once again, I will invite our witnesses to summarize their statements, if they would. I will put the statements in the record.

If we could proceed with Professor Baumann.

**STATEMENTS OF DWIGHT BAUMANN, PROFESSOR, CENTER FOR ENTREPRENEURIAL DEVELOPMENT, CARNEGIE-MELLON UNIVERSITY; DR. DAVID L. MORRISON, EXECUTIVE VICE PRESIDENT AND DIRECTOR, IIT RESEARCH INSTITUTE; NAM P. SUH, PROFESSOR DIRECTOR, LABORATORY FOR MANUFACTURING AND PRODUCTIVITY, AND PROFESSOR OF MECHANICAL ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY; AND DR. GERALD G. UDELL, DIRECTOR AND ASSOCIATE PROFESSOR, INNOVATION CENTER, COLLEGE OF BUSINESS ADMINISTRATION, UNIVERSITY OF OREGON**

Mr. BAUMANN. Mr. Chairman, I'm the director of the Center for Entrepreneurial Development, Carnegie-Mellon University, an institution which we founded in 1971, after spending about 10 years in making the decision that it would be possible to institutionalize the development of embryonic new companies, and that one could in fact build—an incubation center in which companies could be founded and would flourish.

I think our results thus far show that it is possible. We have noticed in the literature about entrepreneurship that there are some activities that appear to happen around universities, like MIT or Stanford, that seem to be causal in the development of new companies.

I moved to Pittsburgh in 1970 to see if it was possible to make such a thing happen in an environment that was not known for being innovative. But I would like to address my brief comments first to the hypothesis that what has been talked about in these hearings thus far is akin to the grandmothers of industry and grandfathers from universities and Government sitting around and talking about what kind of babies their children should have. And it has about the same relationship, to the actual creation of a viable product.

I think what we need in the case of innovation is not more advice, but more of the action. We need Masters and Johnson type of research to understand the dysfunctions of innovation; we need John Rock fertility clinics for innovation; we need ways that address the question of why more babies aren't happening.

I think Dr. Branscomb touched on one. I think the present people who are capable of having babies are not secure enough in their prediction of the future, and the uncertainty of the economic or regulatory environment is something I did address in my testimony. I think that's fatal.

On the other hand, I think in fact that our universities are producing people who are innovative and capable of creating new

ideas and bringing them to the marketplace. But the percentage of those people that are produced each year is very small. I think it's less than 1 percent. And we are absorbing a large fraction of that 1 percent into the role of developing regulations and working around regulations, and thus fewer are left to develop the market innovations that we have come to expect in our economy.

I think the real shortage we have is not energy. Our shortage is of foresight of a secure future, and our shortage is of those classes of innovative, creative people that are now being diverted into issues that, I agree, improve the economy, but they improve it locally and nationally and they make us uncompetitive on an international basis.

I think some of the innovation energy that we are putting into regulations essentially helps the economy. It's not unlike what happened in 1933, when we had a lot of unemployable members of our society, so we gave them long-handled shovels and had them dig ditches. We have unemployable members of our present society. We give them law degrees and clipboards and have them do regulations.

Let me just briefly mention what we have been doing at Carnegie-Mellon University. We have invented a new kind of institution—and my testimony tells why. This kind of institution is a teaching hospital, in which entrepreneurs are developed. This center is a studio in which this maternity ward, incubation function might take place. We think there are a great number of people who are completely qualified to be parents, to be innovators, to have a new company, to have a new idea. However they have been dissuaded by the environment of the university, first, by the environment caused by the funding that the university has been receiving and thus from its emphasis on pure science and its considerable concern with the issue of conflict of interests, particularly the red herring called patent policy. These young people have not seen industrial role models in the universities except a very few places where there have been these natural incubation centers—MIT, Stanford, et cetera.

I think we can replicate the natural centers and put them into other places. We have started 12 companies in Pittsburgh around the university. Students are participating in these companies. They are the founders and owners of these companies, and the role models this produces has very broad impact. I expect a great change in the way the present graduates of our university view business, simply because they were present when the role model was being developed. They didn't necessarily have to be involved personally. They were involved through contacts with people who were involved.

A simplified way of looking at our centers is that it is very similar to the small business program of the National Science Foundation that Dr. Atkinson talked about this morning. Essentially, we take potentially entrepreneurial innovators and we help them at the project startup phase, just as they do in the small business program, except we are also dealing with a new small business. We help them in the next phase to bring in venture capital, and when the venture capital people come in, and give help, we relinquish our position on the board. We then have the

venture capital people participate on the boards; they are then supplying the sustenance, the experience and the background necessary for the next stages of capital formation.

As for the inexperienced people who come to us, they are otherwise fully qualified. In most cases they are people we have dealt with for several years in the graduate school. I have a board of experts that help me evaluate them and their ideas, and to help them when they get into difficulty. Our primary role is to provide the experience they do not have, and in some cases the initial out-of-pocket funds they do not have.

Most of our new businesses come about because someone who is well prepared also happened to be lucky enough to be well financed, either through his family or through immediate friends. We think what we are doing in the innovation center is dealing with financing of new business startups as an embryonic process, as contrasted to the Small Business Administration approach, which tries to finance them in the geriatric stage.

I think it is also the proper role of government, to try to asssit business at the time it starts to assist in assuring viability. I think our center is not in competition with any other kind of institution. Venture capitalists don't deal with early startups. Finders and consultants don't often deal with startups. People in startup phases can't afford to pay for the services. In our case, services are supplied to the new venture from a nonprofit, revolving fund to which they also will contribute via stock and repayment of loans.

Someone who deals with startups has to be willing to take a risk on the potential of the individual, and I maintain that the university system, particularly the private university system, is the institution in this country that has shown the best capability of handling that decision process to deal with the people who have the most ability. We talk a great deal about developing employees and jobs. We are talking about developing employers and opportunities.

Thank you.

Senator STEVENSON. Thank you, sir.

Dr. Morrison?

[The statement of follows:]

STATEMENT OF DWIGHT M. BAUMANN, PROFESSOR OF ENGINEERING DESIGN, CARNEGIE-MELLON UNIVERSITY, AND PRESIDENT/DIRECTOR OF THE CENTER FOR ENTREPRENEURIAL DEVELOPMENT, INC.

Mr. Chairman, gentlemen, my name is Dwight Baumann. I am Professor of Engineering Design at Carnegie-Mellon University and also am the President/Executive Director of the Center for Entrepreneurial Development, Inc., a non-profit institution affiliated with Carnegie-Mellon University and organized for the expressed purpose of studying the develpment of new enterprises in a clinical environment while assisting the incubation of new enterprises. The clinic functions as a teaching hospital. The patients are entrepreneur/investors who have convinced us of their abilities and their drive in organizing a new enterprise and, furthermore, have needs that are within the capability of the Center, its staff and resources to be of assistance.

I was born and raised in the State of North Dakota. I attended North Dakota Agricultural College where I received my Bachelor of Science degree in engineering in 1955. I attended M.I.T. on full scholarship for my Doctor of Sicnece degree and served on the faculty of M.I.T. for 15 years in the Department of Mechanical Engineering. I moved to Carnegie-Mellon University in 1970 to head up the interdisciplinary graduate program in Engineering Design and to initiate the Center for Entrepreneurial Development. I was attracted to Pittsburgh because the City did not have an image of being a center of new enterprise development. The heavy industries in the area did not have the image of spinning out new technologies and

new companies and, in general, it looked like a good place to initiate some experiments in entrepreneurial development.

Carnegie-Mellon is a university, organized around Carnegie Institute of Technology and the Mellon Institute. It has long been involved in innovative ideas, but had not been so successful as to stifle the creation of new activities. I shall speak more about the institutional aspect later. It is interesting to note that the Mellon Institute is perhaps a precedessor and grandfather of the cooperative research center idea. Found in 1911 by Robert Kennedy Duncan, its purpose was to provide cooperative facilities for the embryonic, basic industries in the Pittsburgh community. Various companies would supply funds and, in some cases, key research personnel for a fellowship program. In some cases a research position was endowed. All these activities were focused on applied research. Joint facilities in terms of a library, laboratory equipment, building space and so on were provided by endowment from the Mellor banking family.

In recent times, the Mellon Institute concept has declined because many of the industries prospered and developed their own more extensive research facilities. Mellon Institute was reorganized into the Mellon Institute of Science and the Carnegie-Mellon Institute of Research. The latter is now attempting to reestablish its preeminence as a cooperative research center. In passing, I find it interesting that at these hearings on S. 1250, there appears to be a coincidental tie to Carnegie Tech and its environment of innovation in several dimensions. Jack Goldman already testified that he was a professor at Carnegie Tech for five years. Professor Nam Suh from M.I.T. has his Ph.D. from Carnegie Tech, and I am presently on the faculty at that institution.

First let me address some of the questions that were asked by members of the Senate committee during the hearings on June 21. In particular, I should like to talk first about the issue of institutional framework and historical precedences. Next I shall address the question of the innovation process and the reasons for government involvement at this time, and finally I shall address some of the details of S. 1250.

## INSTITUTIONAL ISSUES

Thus far at these hearings, we have heard testimony regarding the Morrow Act and NACA. In the Domestic Policy Review report by Jack Goldman's committee, there was reference to the Office of Naval Research. All have been proposed as models for the Centers for Industrial Technology. Although the historian, Huxley, points out that we learn from history that man doesn't learn very much history, I would like to draw some tentative conclusions and suggestions about the institutional issues. First and foremost, I think we should be aware, and certainly members of any organization which must be elected by a constituency are aware, that an institution is people. In particular, each kind of institution has its heroes whose names are synonymous with the institution. as someone once pointed out, "Search all your parks in all your cities, you'll find no statutes to committees."

The Office of Naval Research, for example, was the product of Admiral Louis de Florez, who much like Admiral Rickover, was a creative, inconoclastic but wise and influential individual. He established a research flavor that fully understood that the results of research were of no value to the Navy until someone began to manufacture the product. At the same time, he also understood that a minimum of bureaucracy would be endured by the truly creative people whom he wished to attach to work on problems for the Navy. The flavor of the organization he created lasted beyond his own lifetime, but perhaps now is also changing.

As a young assistant professor at M.I.T., I was supported by a contract from the Office of Naval Research in developing some optical character recognition and pattern recognition techniques as well as optical high-density data storage devices. My hope was that we could automate the library. As my research progressed, my contracting officer at the Office of Naval Research, who is no longer with the organization, took me to lunch one day and explained some facts of life. He pointed out that within his organization, they did not obtain "brownie points" unless the results of their work made it into the marketplace and were finally available to the use of the Navy. He explained that therefore an informal procedure had developed that would finance one major contract to a principal investigator who would start a company to manufacture that product. I did not accept his advice at that time, and we have since both gone our separate ways. However enlighted self-interest with appropriate control of conflict of interest, is the mechanism of entrepreneurship around the world.

At the Center for Entrepreneurial Development, we are entirely aware that entrepreneurship is not limited to the capitalistic free-market system. Some dictionaries define an entrepreneur as a person who takes a risk with his reputation, his position or his finances. We find that many people who presumably are taking a

risk in the financial and industrial world are not doing it for simple greed or financial reward. A great share of them are doing it for the power and ego gratification. That is why the corporate income tax and graduated personal income taxes did not result in the death of capitalism.

We believe that the mayor of a city, or the governor of a state, in fact, is entrepreneurial. He suggests some ideas and courses of action, thus taking a risk of his position or reputation that in fact people will agree with his perceptions. the perceptions must be as creative as are the new products that are introduced in the marketplace. An idea can be ahead of its time in the same way that an automobile or a consumer product can be ahead of its time. It can be behind the time, it can be dull and drab, it can be misunderstood.

At Carnegie-Mellon University, our Center for Entrepreneurial Development is thus a joint venture of the School of Urban and Public Affairs, the School of Business, and the School of Engineering. The broad definition of entrepreneur that we have been using thus encompasses all acts of leadership and creativity except perhaps those in fine arts and pure science. I might add that entrepreneurial activities in Red China and the U.S.S.R. operate on a similar basis of reliance upon the individual for creativity, the taking of a risk with that creative position, and finally, the voting or the paying that rewards risk via the collective action of those who appreciate the creative act and the risk entailed—the aberrations and truncations of the voting and the financial marketplaces withstanding.

The American university and the university laboratory has twice before been called upon to solve social problems. The first as has already been mentioned was agriculture, and the result was excellence in agriculture. In the second instance, during and following World War II, the university through laboratories like the Radiation Laboratory at M.I.T., the Jet Propulsion Laboratory and others became involved with similar results. The success of the laboratories at M.I.T. was probably significantly enhanced by prior policy that M.I.T. as a struggling institution allowed, even encouraged its faculty to spend one day a week in consulting or other applied activities.

Jackson and Moreland, Stone and Webster, Arthur D. Little and other organizations were developed during this stage. When World War II approached, the faculty was qualified at applications of science, and their pragmatic approach was applied to the defense laboratories. The defense era was artificially enhanced by the aerospace era which was really a continuation of the defense activities. Essentially, John Kennedy and the Congress understood the mechanism of artificially prolonging the era and enhancing the economy because it utilized the same institutions and laboratories that had been active in defense. Certainly the Sputnik development galvanized this approach. Each of these two prior eras had an economic cyle associated with them as the technologies matured. The government laboratories were developed as institutions similar to the laboratory of the university (a spin out) because of the secrecy requirement that was foreign to the university's goals.

This post-aerospace era, the urban era, has a clientele which is similar to that of the agricultural era. The customer is, in fact, us. During the aerospace period, the customer was the Joint Chiefs of Staff or the NASA administrators, who were given the authorization by society to deal on its behalf with the technological procurements. The were also the customers for both the technology and the products.

In this, the urban era, we find that the products are no longer limited to consumer goods, but include services and quality of life issues such as air pollution, conservation, public transportation. social welfare programs for the elderly, etc. Since the consumer of urban technology is similar to the consumer of agricultural technology at the time when America was primarily rural, the extension service idea is attractive. Its significant differences however are the ones that we need to address in developing an institution for industrial innovation and technology. Similarly, we need to address the comparison of the required institutions with the government laboratory models developed during the aerospace era.

First, let us deal with the technology transfer agent Professor Hollomon referred to last week. As a farm boy from North Dakota, I was the recipient of the Extension Service's technology transfer. A large portion of its activity was training the youth in good agricultural practices through the 4H-Clubs. Many ambitious leaders have long recognized the advantage of working with young people in organizing a revolution. At the time that the Agricultural Extension Service was developed however, there was not a profession of technology transfer for agriculture, and the ongoing research needed to be translated to a relatively ill-prepared and uneducated society. In the case of the industrial technology, there are many millions of transfer agents already active in transferring science to societal use; they are called engineers.

The problem with the extension service idea proposed by Herbert Hollomon when he was Assistant Secretary of Commerce is that it competes directly with the

engineering profession, management consultants, and others. It proposes to put the government into the business of being management and technical consultants at a time when these professions are already well developed. In the case of agricultural research, each farmer did not need the entire services of an animal husbandry expert, a plant breeder, or botanist. In fact, he may have only been the user of one thousandth or one ten-thousandth of a full time professional. The justification of the research or even of the technology delivery of the service supplied by the government is very similar to the justification for having the post office or the defense department be a function of government. In the case of industry, each company does, in fact, need to have its own engineers, its own managers, and its own bookkeepers and accountants. In most cases it needs at least one of each in order to be a bona fide company. Thus, if the government were to supply the personnel to fill those roles, there is no place to draw the line between government supplied professionals and the industry supplied assistants. Carried to its conclusion, corporations might consist of computers who send requests to government agencies for technical and management assistance and the professionals would be employed by government. I think this is not the model that makes sense in terms of maximizing industrial innovation for America. Furthermore, the kinds of information that can be found in libraries does not need to be read and translated to the end users today as was needed in the past.

In a related sense there is another significant difference between the Agricultural Extension Service and the industrial sectors' technical problems. Individual farmers do not feel that they are competing with each other. They may be competing with the weather, disease, etc., but normally, they will brag about and help each other to utilize the technology that they discover. As Herbert Hollomon has pointed out, innovation is not the same as research. It includes carrying the idea all the way to the marketplace. The marketplace issues are at the very gonads of an industry's existence. It is, therefore, very customary for people who consult with industry to have exclusive contracts that limit them from working with industry to have exclusive contracts that limit them from working with competitors. The kind of technology that one might learn about in most present universities must be augmented by a kind of experience that is only learned from practice. Most managers of business are concerned that the mistakes as well as the successes made by their organizations represent a cost and financial advantage that should not be of benefit to their competitors. In order to deal with this secrecy issue, our Center has a policy of dealing in a major way with only one industry of each kind.

NACA has been mentioned as a cooperative program with an industry, but I think we all realize that it was a very narrow portion of industry. Within that industry, it was directed toward some important but well-defined optimization problem but still it was not as global as the proposed Centers of S. 1250.

Jack Goldman in his testimony pointed out the advantages of companies working together on various specific copies, particularly when it was possible to ameliorate the conflict of interest issues with regard to criticism of collusion. In that regard, our society has some very strange concepts of conflict of interest. While Congress and the Administration was adamant in making sure that the clean-up of the automotive emissions was done separately by the automotive companies, the same group of actors including Henry Ford as a person, the Ford Motor Company, General Motors, Fisher Body and others have been colluding in the development of the Renaissance Center in Detroit with everyone's apparent blessing. In fact, some of the members of the American automotive industry will certainly make more profit out of their participation in the Renaissance Center than out of their primary business.

The Japanese certainly appear to consider some of the issues that we consider to be conflict of interest from the viewpoint of commonality of interest are, in fact, the same concept from a different point of view. I believe that the Congress should spend some time dealing with definitions of conflict and commonality in a number of areas. As was pointed out in earlier testimony, in international market issues, it is apparent that collective approaches are necessary. I believe that some of these can be undertaken without direct government action. It is interesting to note that whatever the form of government, Adam Smith economics prevails in international trade between independent nations.

In the case of NACA model, Dr. Milton C. Shaw, now on leave from Carnegie-Mellon University and incidentally the thesis supervisor and mentor of Professor Nam Suh, originated the concept of the Processing Research Institute at Carnegie-Mellon University in 1971. He had been a division chief at NACA and his wide experiences suggested an experiment that was funded for five years by the National Science Foundation. He investigated cooperative research with individual companies on the basis of NSF supplied matching grants to initiate the relationship with the

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hopeful expectation of further funding from private sources alone. While that laboratory does not continue due to changes in personnel, illness and other individual issues, the experiment in transferring the NACA model into the university and working with individual companies developed some understanding of what should be expected to be a problem in the Center for Industrial Technology proposed by S. 1250. Many of the projects which were initiated with various companies progressed to the point where the legal department of major companies had to sign off on the contracts. At that time, a number failed because of the patent clauses. In some cases, to avoid embarrassment the companies went forward with 100 percent of the funding and no goverment subsidy, in order to protect all of the patent rights to their exclusive use. In others, the project never got off the ground. When the matching funds ran out and it was no longer possible to "hold out-the-carrot," it became more difficult to attract the initial industrial interest. Essentially then, the experiment showed a "catch-22" phenomenon. Certain members of large corporations became interested in the cooperative aspects; the legal funds, the relationship became less attractive. In the case of Professsor Nam Suh's activity at M.I.T., there is perhaps a considerable aspect of companies being willing to spend certain amounts of money to reside in the afterglow of a M.I.T. relationship.

In an earlier involvement by Professor Shaw with the Grinding Wheel Institute, he was supported for many years in developing an understanding of the process of grinding. The relationship appeared to be a healthy one until he made what some consider to be a significant invention of a segmented grinding wheel. The relationship became stormier and stormier. All of the rights, of course, accrued to the Grinding Wheel Industry which meant that each of the members had royalty-free rights to practice the art. While it was never clearly articulated, it became somewhat obvious that the research directors at the various organizations thought that Professor Shaw's work should have dealt only with fundamentals and that at the point where an invention might be made, he should have ceased in his curiosity and allowed certain individual members of the Grinding Wheel Institute to be the inventors. Some of this flavor of concern for control by industry also presented itself at the public meeting of the Subcommittee on Direct Federal Support of R. & D. of the Domestic Policy Review of Industrial Innovation on January 16, 1979. Industrial members of the committere want complete control of both the initation and the discontinuation of research at the Centers.

The relationship between the industrial members and individual professors in a cooperative research program is complex, but the personal issues do often play the predominant role. The director of research for a manufacturing concern is really hired to do product development. This is also very much the same as the current "buzz word," innovation. Individual inventors often find it difficult to sell their inventions to large corporations because the president of the corporation will ask the research director to comment on the invention. The proper answer from the research director is often the same as the proper answer to "When did you stop beating your wife?" If he admits that the idea is good, then he can be asked why his organization, the research laboratory, hasn't done as well or better. If he says that it is bad and the president has already decided to do it, then his judgment is questioned. As one of my friends has pointed out, one need almost never be concerned about telling an engineer about an invention because engineers are successful by having a better idea. Thus they will respond accordingly. The same friend pointed out that successful lawyers become so from finding appropriate ideas in the case law, and thus they have little reluctance to appropriate ideas.

The government laboratory model, in as much as it may be different from the NACA model, also needs to be discussed. First of all, it is a model that came about primarily from research and in some cases, from very job-specific engineering and development where secrecy and privacy were the issue. In an environment that cannot be covered by the rules of government security, the results of development work in a government laboratory are available to everyone. I believe that there is significant evidence that foreign industries have benefited more, or at least as much, from the work of American governmental laboratories as have American industries. The transfer of information is not impeded by distance. The development of the government laboratory model in an open society is thus more beneficial to those who have developed a good mechanism for borrowing and appropriating technology, and American industry, particularly big business, has not been particularly good at this kind of technology transfer. Witness their poor record in buying and using patents.

The best way to transfer technology is to transfer the people who developed it or to help those people who developed the idea take it all the way to the marketplace. People tend to stay where the environment helps them or where they are when they become involved. Detroit happened to Michigan because Henry Ford grew up

there. The process continues. Polaroid happened to Boston for the same reasons. Xerox traveled to Rochester because the environment there was receptive. If timing and a jump on the market is the major competitive edge that can be relied on in a dynamic society then the real issue is to enhance the speed of technological development.

What kind of model then should we use for the Center for Industrial Technology? I believe that a good model is one that deals with developing experienced young people at the prime of their professional life. Such a model was the Instrumentation Laboratory at M.I.T. First of all because Stark Draper was an innovator and thus provided a role model. Secondly, the laboratory had a policy that professional people were employed for only five years. They were told that upon being hired and in many cases, five years later started their own firms. Draper's model, in fact, was an intermixture created by his role as head of the Aeronautical Department at M.I.T.; and he was, first of all, a professor and secondly, an innovator. His professor role meant that he was most comfortable where there was a throughput of people. He kept viable by having young move through the system. If one investigates in depth, the 128 phenomenon, one finds a predominant number of Draper's students. Similarly, if one investigates the Silicon Valley, one finds a significant number of Fred Terman of Stanford's student and their proteges and direct descendents. We thus conclude that the incubation process also has its heroes as a role model, and that the institution itself may last longer than their founders if the throughput of people has forced it to become organized for renewal.

We learn for history, however, that none of the agricultural colleges or universities based around the extension-service, land-grant idea played a predominant role in the defense and aerospace era. Certainly the faculty at the land grant schools were as pragmatic as they were at Stanford, Cal Tech, or M.I.T. But somehow, the political atmospheres at Michigan State, or Penn State and others did not allow significant risk-taking by enterpreneurial faculties at the time when the defense era was beginning. At the University of Illinois where the land grant college and the University were, in fact, merged into one, relatively little aerospace work was done as compared to the giants. Cornell's involvement was in a different city. Purdue, Minnesota, Ohio State and other institutions with good engineering and science faculties were also overshadowed. From this, one should suspect that relatively little significant work will be done on the urban problem by those universities that have had their successes in aerospace. Certainly, there may be some notable exceptions simply because of the massive power and prestige of organizations like M.I.T. However, the phenomenon of grandfatherly people standing around, giving advice, wringing their hands and worrying about the future that I saw at North Dakota State Agricultural College as a young student, when the Sputnik appeared on the scene, was repeated at M.I.T. when the principal practioners found that they were no longer the darlings of the funding sources. The agronomists, botanists, and animal husbandry specialists at North Dakota State, and the physicists the aeronautical engineers at M.I.T. behaved similarly at the end of their eras.

Much of the present environment in engineering education was developed by the engineering scientists of the aerospace era. Their students continued in engineering education without the benefit of hands-on experience in engineering applications. Thus we are presently also out of balance in our educational institutions with regard to producing the proper kind of educational eperiences and role models for the present innovational needs of the United States. The way to keep technology which is developed in the United States is to keep the technologist who developed the idea in the cycle, all the way to the marketplace. There has been a significant overemphasis of the myth called technology transfer. It appears so often as some kind of process without including the intellectual and motivational issues of the persons involved in the process. We are all aware of the concept, NIH (Not Invented Here), and I have briefly alluded to it previously in this testimony. Peter Drucker has suggested that we can divide technologists, and that really includes the managers of technology, into three categories: first, those who make things happen; second, those who understand what happens; and third, those who wonder what happens. Those in category one are a very small minority, even in our institutes of technology and schools of engineering.

The role of technology in our society is changing. Much of the creative effort normally associated with engineering is presently being absorbed in complying with the regulations imposed on industry through administrative law. An equivalent component of creativity is also employed in the development of the regulatory details, the measurement and implementation procedures, as well as in the area of enforcement, and in the inevitable compromises that deal with the trade-offs between what is desired and what can practicably be accomplished.

Every weld location on every automobile design drawing is being checked and identified for certification requirements within the National Highway Safety Administration. It is hard to delineate whether the product design process takes place in Detroit or in Washington. That aspect of innovation which is associated with setting performance specifications and deciding on the allocation of resources and costs is perhaps more impacted and involved within the regulatory proceedings, and thus it is difficult to say who actually makes the decisions on new products and whether the areas of potential innovation are so prescribed as to be excessively costly. Professor Meade testified last week that even the semiconductor industry has become so complex as to limit new improvement innovations.

The traditions of engineering are thus being reexamined. Needless to say, the engineering profession has not paid much attention to its traditions because as a change agent of society, it has either responded to conditions or, in some cases, created them. We need not go into the old harangue about science versus engineering except to focus briefly on the oft-heard statement that a technological success is considered to be a success of science; a failure is ascribed to the engineers. That overstatement, while loaded with the possible pessimistic bias that comes with a profession that always balances success and defeat, barely describes some of the relationships between engineering and science that should be readdressed. True science is, of course, apolitical, amoral, a-ethical because it attempts to strive for knowledge. Truly, such knowledge can be misapplied, and thus there are many scientists who are concerned that there should be some control on what kind of knowledge is developed and by whom. Most of these arguments, however, are used by scientists to describe their wishes to control the work of others; seldom have they been willing to consider the possibility of their own work being controlled.

The application of science, however, is and has been in the realm of trained engineers for a relatively short period of our history. The formal education of engineers is a relatively new human invention. While it is an invention of society rather than an individual, we should try to understand what society was trying to accomplish as it developed the concept of engineering education. Students of the history of technology tell us that there was no clear formation of the profession of engineering. Clearly the early Greek scholars and philosophers were also engineers, and equivalently, engineers were also being trained by working with the engineers of earlier civilizations.

The real growth of the engineering educational institutions occurred during the rapid industrialization of the United States. The hero at the time when engineering colleges were being developed, when the Congress had set aside the land grants for agriculture and mechanical education and when the institutes of technology were formed were clearly the American industrialists. The role models of Henry Ford, Tom Edison, George Westinghouse, and numerous others were household topics of discussion. During his lifetime, Edison was considered to be the best known person in the world. His impact on everything from electric industry to the arts, the talking machine and the motion picture, as well as on the chemical industries, the mining industries, plastics industry were well known. The institutes of technology were formed to replicate this American industrialist-technologist, and the industrial developments and corresponding feedback to the education developments are well known. In the style of early industrial America, we set up institutions to mass produce engineers with little quality control except for being concerned that all were gainfully employed.

We should recall, however, that the role models for the development of institutes of technology and the engineering schools were not Edison's helpers or Ford's engineers, but Edison and Ford themselves. They were the people who made things happen, who took responsibility, who organized capital and the people into a goal-oriented institution. Edison is credited with inventing the industrial research laboratory. The concept of applied research was, in fact, newly formulated during this period. The technologist has always been clever enough to define his work as being applied science when the fund sources were looking for applied work and pure science when the opposite was true. The definition perhaps comes more from the sources and potential sources of funds, ego gratification, peer approval than it does from the distinction between methodology or methodology background or philosophical inclination. Man has, in fact, a basic drive and necessity to be creative and also a basic appreciation for the creative act wherever it is found: creative science and creative art. Creative engineering acts are appreciated in the eye of the beholder according to the backgrounds and abilities of the beholder to understand the issues. The kind of creative act needed to impress one's peers, to excite students, to gain encouragement and support differs from profession to profession. Man, by his very nature, identifies and responds respectfully and appreciatively to the changes that are made by creative persons—creating a new theory, creating a new method

of analysis, creating a new method of presentation, creating a new machine, creating a painting or a symphony are all interrelated but improbable acts of the human intellect. The definition of creativity itself often eludes us because the rationalist tries to find ways to describe the entire universe in a few simple words. The working definition that encompasses all human acts of creativity is that the creative act is, "that act done by others which we wish we had done ourselves."

The creative engineer (*engin.*—from the medievel for native talent, hence something produced by this) is thus the innovator for which the Domestic Policy Review Advisory Committee on Federal Policy on Industrial Innovation has been seeking. He is, however, not easily found because he is rare, in his pure form and is presently otherwise involved. To borrow again from Peter Drucker's concept, the engineers who can make things happen are a small part of the yield of our present institutionalized production of trained engineers. I believe that on the order of one percent of our engineering graduates at present fit the "make things happen" category. In the past, this has been adequate to keep the other 99 percent quite fully employed and thus the rest of the technologically-based U.S. economy. Now we either need to produce more of this 1 percent type, divert fewer to other pursuits (regulation, etc.) or accept the idea that other cultures will and are developing their own dynamics of product innovation based on their own evolution from an agrarian economy that fosters the first principles of self-reliance to a self-reliance with technological product growth dynamics. The limits of growth have not yet been reached and will not until technology reaches its limits of finding substitutes for necessary resources.

The governmental involvement in directing efforts of our scarcest resource, creative people, via policy and funding decisions have created our present apparent lack of relative industrial innovation as is especially apparent when one regards the international scene. Many of the present innovation resources are directed elsewhere and many are not being fully utilized because our present state of uncertainty of our financial environment and our fiscal and regulatory policies. While crisis and uncertainty often breed invention, innovation requires financial and political stability. Thus is will require the policy and funding changes of S. 1250 and more to begin to redress the present situation.

In support of this conclusion of the necessity for change in engineering at the educational level, I have asked Professor Milton C. Shaw for his perceptions. These are included in his letter as an addendum to this testimony. We agree with Dr. Hollomon that the educational system itself needs to be changed to prepare for the challenges of a civilian, world-market economy. Ingenuity (from the same base word as engineer) and the political and economic environment in which the United States continues to respect, support and be enthused by basic and improvement innovations will be enhanced by the focus on policy and financial assistance to local institutions that could be provided by S. 1250.

### UNDERSTANDING AND DEVELOPING MORE INNOVATORS/ENTREPRENEURS

The area of entrepreneurship is quite difficult to study. Most of what we know about it is anecdotal, after the fact, and colored by a lot of the relections—most of them incorrect—of people who were entrepreneurial at one time. We find it very difficult to evaluate clinically what happens because of this retrospective attitude and because egos are involved. Ego, in fact, seems to be one the primary ingredients which allows people to undertake the improbable events that are associated with entrepreneurship.

Entrepreneurship is a multiplicity of creative events. We believe that the technological entrepreneur is the "compleate designer" in the sense of "compleate fisherman." He must design or select the project or product; there are various degrees of creativity associated with being a good selector or a good designer. If there are very similar ideas, he must survey a number of possibilities and decide what is a useful, a saleable, an exciting concept. Pyschologists tells us that the purchaser often goes through an "aha experience" not unlike the inventor, when he sees and appreciates a new product.

In addition, however, the entrepreneur must also select an organizational structure, a way to approach the capital market, and a way to find people who will invest in the idea. He must design or invent a way to organize colleagues who will help him; he needs a complementary set of people with complementary characteristics. Thus, he essentially is designing a business system, a market approach, a financial approach, and a product system. The most "compleate" entrepreneur or the most "compleate" designer, in the context that we are using here, would be the person who was the most understandably creative in each of these dimensions.

Since we have defined creativity as "that act done by others which we wish we had cone ourselves," essentially the creative act is an improbable act. In other

words, we, in a non-pejorative sense, are envious of the act. Any act which is an outgrowth of some theory, some recipe, or some set of predictive processes which is incapable of coming up with surprises will not be considered creative by the majority. Here we borrow from one of Rabinow's ideas, that there is a tie between a good joke and an invention, because the surprise ending follows a general development of logical developments. These surprises really mean that invention will not be capable of being modeled in the normal way of modeling scientific theories. While modeling techniques usually predict higly probable solutions, we are basically dealing with improbable solutions—just improbable enough to be surprising, not so improbable as to be shocking (although even the shocking ones, with a fair amount of market education, can be successful). In a sense what we are saying is that the teaching of entrepreneurship and, if possible, involvement with entrepreneurship, is a third power or a fourth power of difficulty over the teaching of design itself. When people in the design education field talk about what to do, and what not to do, and generally spin anecdotal stories, most of the stories are understood only by the people who were, or are, engineering designers. We somehow assume that the students will understand them because they are being spun out by people who have experience in the field, even if it is vicarious and often shallow. It is quite possible that most of the words don't mean very much in that context expect to the other old professors who sit and nod and say, "Yes, that's how it is."

What we have been doing at Carnegie-Mellon, in the face of this basic philosophy, is to accept the fact that understanding and, eventually, learning to develop entrepreneurs will be difficult. We know that the body of knowledge and the theories will probably not be very good. Yet we believe this should not keep us trying to find and understand some of the critical ingredients. In a sense our philosophy is that this topic of entrepreneurship—of multidimensional creativity—will be understood best in a clinical or a studio environment. At this stage, what we need is the technical and financial equivalent of the old barn and the experienced painter to see if we can start an art colony. The students learn by participating in more and more challenging activities with benevolent criticism.

The real innvovation at the Carnegie-Mellon Center, as far as I am concerned, is that we have developed an institutional framework for a incubator, or a studio in which entrepreneurs can work and obtain some of their original sustenance to get started. The following statement describes what our studio is all about.

The Center for Entrepreneurial Development, Inc., is a new kind of institution, focused on: Clinical Studies of the entrepreneurial process; technical and management assistance to budding entrepreneurs; a university affiliated not-for-profit corporation to limit financial liability and protect the university's assets; a not-for-profit revolving fund the finance the initial out-of-pocket costs (not for salaries of the principals); and common facilities, low cost rental space, purchased access to the university's services (shop, printing, stories, computers, etc.).

We have set up the Innovation Center at CMU as a separate, nonprofit entity in very much the same manner as a clinic, art studio, or teaching hospital would be set up, and in the same manner in which not-for-profit urban development corporations have been established in various communities. As have the teaching hospital, the agricultural experiment station, and the community development corporation, we have obtained a 501–C–3 IRS status for the corporate structure. The purposes of our corporate charter are:

"To foster entrepreneurial activities and business and industrial projects as vehicles for research and experiment in the teaching and advancement of technology and management science; to assemble information and data, statistics and experience to be used as teaching materials for students of technology and management science and for research projects in those fields; in general, to conduct applied research in any area of enterprise for education purposes and to improve the techniques and methodologies of management in all areas of private enterprise and public affairs."

We think this corporate structure has several important advantages: 1) It is financially apart from the university, so one can attempt greater risk than the normal university environment would allow. It allows the Center to do the things that corporate structure is basically designed to do; i.e., limit the liability to the specific project. 2) It allows the Center to have a more effective means of monitoring what is happening and of keeping the finances separate so the experimental nature of the entrepreneurial process and the business start-up process can be observed.

The separate legal entity and its separable political aspect is very important in that it provides a number of freedoms that would be even more important at a nonprivate university. We have a corporate separation and yet we have a synergistic relationship to the university in that the deans of the schools of business, urban and public affairs, and engineering are members of the board of the corporation.

This means that relationships between individual professors who might be involved with the Center and the university can be monitored at some point, and release time for people who are going off to start businesses, payments for services received, and licensing of ideas outside of the university can be expedited. Associated with this framework, we have been involved in developing a number of courses and there is considerable opportunity for research projects and design projects, which can be done for university course credit.

The Center for Entrepreneurial Development has two parts: academic and clinical. The academic aspect of the Center exists within the university context but, as soon as a project gets to the stage where it needs a corporate structure, then it is moved into CED Incorporated, a free-standing nonprofit corporation. CED Inc. is a subcontractor to the NSF project. The separate corporation allows us certain structural advantages. The engineering side of the program is primarily based in the Engineering Design Program, which offers a 2 year interdisciplinary Master of Engineering degree.

A list of current projects with CED Inc., is shown in Figure 1. Our first project was begun in 1971 when the Center was organized.

CED PROJECTS AS OF DEC. 1978

| COMPANY | CENTER INVESTMENT | # OF EMPLOYEES | GROSS SALES | CORPORATE TAX | WITHHOLDING TAX | NEW CAPITAL | BRANCHES |
|---|---|---|---|---|---|---|---|
| 1. Compuguard | $40,000 | 110 | $4,700,000 | None | $370,525 | $3,750,000 | 5 |
| 2. Vectran | $20,000 | 17 | $790,000 | $41,000 | $85,000 | None | None |
| 3. Transcomm | None | 50 | $8,000,000 | N/A | N/A | N/A | 3 |
| 4. Three Rivers Computer | None | 8 FT<br>11 PT & Contract | 800,000* | N/A | N/A | N/A | One agent on West Coast |
| 5. Sun Publications | $1,000 | 6 FT*<br>15 PT* | $175,000* | N/A | N/A | N/A | None |
| 6. Peoples Cab | None | 39 | $215,000 | $1,500 | $36,000 | None | None |
| 7. Peoples Travel | None | 4 | $800,000 | N/A | N/A | None | None |
| 8. Iron Clad Agreement | None | 7 FT<br>1 PT | $100,000<br>($27,000 Earned Income) | None(Non-Profit) | $10,500 | None | None |
| 9. Jessika | $40,000 | 3* | N/A | N/A | N/A | $18,500* | None* |
| 10. Bactex | $60,000 | 4 | N/A | N/A | N/A | N/A | None |
| 11. International Lamp | $500 | ---------- | Out of Business, no losses ---------- | | | | |
| 12. Rehabilitation Equipment, Inc.** | None | 1 | $31,000* | N/A | N/A | N/A | None |

*1977 figures, 1978 figures N/A

** Closed temporarily during 1978 for health reasons, since reopened.

Figure 1.

In each case where the chart shows a Center investment, made in the form of services or payment of out-of-pocket costs by the Center, there is a small portion of stock assigned to the nonprofit revolving fund to help defray the potential losses due to unsuccessful ventures. The Center does not cover the cost of salaries to the principals. Those must be covered by the entrepreneurs.

By the time the NSF experiment started in 1973, we had some experience in that Joe Sigel, a young man who was in our entrepreneurship course and who was interested in the advertising business, did a project in the course and ended up with three local advertising newspapers.

At that time, we also acquired the assets of a bankrupt taxicab company for one dollar. The taxi industry in the U.S. has twice as as large in annual revenue as the mass transit industry; it is about a $4 billion a year business. With all the activities in the elderly and handicapped area, there is a potential for expansion of that business, particularly if some operating efficiencies can be developed. What we have been doing in the research area—supported separately by the Department of Transportation—is to look at the paratransit possibilities that are associated with increasing the efficiency of the taxi paratransit industry. There are many ways to increase the efficiency because, basically, taxi fleets run empty half of the time and have an average of 1–2 persons in them the other half. Thus, if one can sell the back-haul space, or share the ride on the forward direction, efficiency factors of 2, or maybe even 4 might be obtained. Furthermore, there are a variety of opportunities for occasional taxis or commercialized ride sharing. The cab company is a completely separate operation in its research support, and it is now beginning to spin out some technology. We are organizing a company to market that technology. This part of our activity is an urban experiment station for service innovations.

Bactex Corporation, currently with about $55,000 of the Center's investment, is a project with the University of Pittsburgh in biological research. Patents are being developed by the Center. This came about when the University of Pittsburgh observed that even though Jonas Salk was on their faculty and Salk Vaccine had been developed there, the University had never enjoyed any of the resulting revenue. It was hoped that some mechanism could be developed to guarantee a return to the laboratory and the university. Three Rivers Computer Company was a spin out of Carnegie-Mellon University's computer center. Jessica Corporation is developing a noninvasive blood oximeter generated in the C-MU bioengineering laboratory. It is now going through its clinical testing. Compuguard Corporation is one of our early companies. It manufactures energy management systems for building complexes. Compugard was one of the very few new companies in the U.S. to attract venture capital in 1973 and '74. The $3.5 million of capital was attracted from Cleveland and Boston because there have been no active venture capital firms in Pittsburgh in recent times. Compugard has paid back the Center and now Midland Ross, Inc. has an option to purchase the remainder of the shares. International Lamp Company is the only one of our business operations that has not survived. It was started by a student, also in the course, who heard about long-life bulbs and thought he had a great future in selling. He discovered he was not very good at selling, and is now out of business; basically, he did not invest a great deal and neither did we. All funds were repaid. The student feels he learned from the experience. Transcom Data Systems was begun by another group of our early design students who started to sell PDP 11 time-sharing services. Recently the company was sold to a division of Compagnie Generale d'Electricite of Paris. They are now franchising computer software systems to a management consulting firm, and bookkeeping operations in Europe. They have been a DEC, OEM distributor for the PDP 11/45 computer with offices in Denver, Los Angeles, and Pittsburgh. Rehabilitation Equipment Company is run by a student who was very much involved in the Opticon distribution, building various kinds of rehabilitation gear. Basically, he was operating a $20–30 thousand a year business. He had open heart surgery and moved to Vermont where he is re-establishing himself, and another C-MU student is doing the Opticon repair.

Aside from these, there have been a couple of other related companies started in Pittsburgh. One is a travel agency, that will eventually be coupled with the taxi company to provide complete transportation service with tickets sold in the cab via radio and computer, to anyplace in the country; essentially we are trying to tie ground transportation to airline transportation. Several of the taxi related developments are potentially being spun out in a corporation that is presently being organized. Some of the ideas presently in early stages of incubation appear below. Among these is the taxi meter which calculates the fare before the trip takes place permitting accurate calculation of shared trips. When route deviation occurs, no one in the vehicle is penalized. The central computer calculates the fare and displays it in the taxi. This prototype is operating in the Peoples Cab fleet in Pittsburgh.

CED, INC. POTENTIAL PROJECTS BEING DEVELOPED AS OF APRIL 1979

Para Comm Inc.—Shared ride taxi meter system which calculates fare from computerized data base.

Perinatronics Co.—Fetal heart monitor (product of bioengineering department).

Peoples Cab Co. Subsidiary—Retrofit compact autos for wheelchair accessibility.

Paratransit Accessories Co.—Roof-signs, computerized destination signs, design services.

Paratransit Management Information System Co.—Lock box accounting and business service.

Potential: Being evaluated—Instant book printing; combined air-ground passenger transportation service; vehicle locator system; low-cost solar power public buildings for occasional use; and, grinding wheel crack detector.

The Canadian Government has begun to develop five Centres of Innovation based entirely on the Carnegie-Mellon Center concept. They are intending to fund their centers for a 10-year experiment however. Because of the long times necessary to stabilize the revolving fund concept, this is entirely appropriate. Two Centres are alreay in place. I am including as a second addendum some public document from our Northern Neighbor that describes their system.

The West German Government has been considering the development of an innovation center for West Berlin. Sweden is close to a decision point on developing centers. Delegates from Finland, Spain, Australia, and New Zealand have visited Carnegie-Mellow University.

Thus, again a technology—the innovation of innovation centers has been implemented abroad, having been acted on by a parliament, before it has even become part of the widely touted Domestic Policy Review. In the DPR it was brought up from the floor in a public meeting by myself and others, who came to see why 10 million dollars worth of NSF experiments on public innovation policy were not already a significant part of the discussion.

Even though there are already two new competitive centers in Canada, the three NSF experimental centers in the U.S. have served as role models and individual professors as mentors to many hundreds of young energetic and well qualified potential and some already successful, technological entrepreneurs for 5 years. It is via this edge in human resources that the U.S. can maintain its technological effectiveness.

Mr. Chairman, there are a great many good inventions produced every year. My office has been so flooded with expectant innovators and invention disclosures that were I to respond to them all, we would have no successful new companies to exemplify our approach. There is also adequate venture capital, even in lean years for numerous technological ventures to be developed. With some of the recent changes in the tax law, more venture funds are becoming apparent. The scarcity that the United States must be concerned with is the scarcity of people with the will to be entrepreneurial in the field of technological innovation. The climate of fiscal and regulatory uncertainty must be changed to indicate a more predictable future, and more young people must be prepared to face these risks.

Mr. Chairman, Gentlemen, I present to you a tested model of an innovation center specifically designed to provide a studio for developing new entrepreneurs via hands-on experience and learning from the interaction with others. We have thus reproduced in a quasi-laboratory setting the so-called incubator effect that has been studies in Boston and Palo Alto. The clinical environment of our Center and the generic innovation centers proposed and implementable under S. 1250 will make a major impact on returning ingenuity to America.

SPECIFIC COMMENTS ON S. 1250

In an earlier staff working draft of what has now become S. 1250, there was a separation into two kinds of centers: The Centers for Industrial Innovation and Centers for Cooperative Research. The present draft of S. 1250 combines some of the ideas of the working draft into a single heading, Centers for Industrial Technology. We believe the prior draft was more appropriate because it recognized the distinction between more basic and more applied activities. The present drafting is unclear on this topic, and thus those who are concerned with the potential competitive nature of the proposed Centers with proprietary, for-profit research laboratories and private consultants will have a more substantial target.

It is our position that the incubatory center concept for developing innovation has presently no competitors. The venture capital community only enters an activity at later stages. Banks are only involved where there is collateral. Professional finders, lawyers, accountants, and others are not supplanted by the innovation center concept. The first stage of innovation is presently most often funded by family and

friends, and we do expect to replace that activity with the innovation center idea. Rather our function and the function of Industrial Innovation Centers would augment this informal system. Most significantly, it is the major thesis of the Innovation Center at Carnegie-Mellon University that there are many well-qualified persons whose basic shortcoming is a lack of experience or a lack of access to capital because their families and immediate friends and contracts are not wealthy. The university and particularly the private university is still the major American institution that deals with people on the basis of their abilities first, in order to help them with their needs. If the university is performing its necesary role of working at the cutting edge and forefront of technology and science, and at providing reliable evaluation of performance of people, then it should be able to assist those whose only shortfall if that, "they have not because they had not."

In the present S. 1250 the language of Section 5 should be carefully compared to the language of the existing legislation for the Department of Commerce. There appears to be a significant restatement of tasks and functions that most certainly already are a part of the Department of Commerce. In particular, the international aspect must certainly be covered by the present function of the Bureau of International Commerce of the Department. Technology assessment aspects, the identification of needs, problems, and opportunities should not require any new legislative action. Technology is also an industry and Commerce most certainly has been studying trade and industry from the beginning. The Senate Committee should be concerned lest this Section 5 is primarily a mechanism to add additional positions or to reorganize Commerce around existing structure with an unnecessary duplication or personnel slots and functions. Particular attention should be paid, as well, to whether or not the present ETIP program of the Department of Commerce, which already responds to the Bureau of Standards and thus to the Assistant Secretary for Science and Technology, is not also redundant with respect to this, enabling legislation.

The ETIP program and the similar Research and Development Incentive (RDI) program in the National Science Foundation were both developed in response to a Presidential task force directive by the William Magruder, White House Committee, in 1972. The National Science Foundation's activities resulted in a number of policy experiments, which support S. 1250 in demonstrating the potential feasibility of Innovation Centers and Cooperative Research Program. The ETIP program, while operating under the same charter except for the expectation that Commerce would be more effective in dealing with industry and thus it should be more concerned with the industrial aspect and NSF should be more concerned with the university, did not produce similar experiments in policy for innovation. An analysis of the successes and failures within both the ETIPO program and the RDI experimental programs in the National Science Foundation, presently called Intergovernmental Science and Public Technology program, should be significantly included in the discussions of the enabling Act of S. 1250. The transfer of the technology of implementation of the Centers developed within the National Science Foundation should be included as a necessary part of S. 1250 by detailing the National Science Foundation to provide personnel and technical assistance to the Commerce Department during the implementation phase of the Centers for Industrial Technology. Certainly the government itself should be an example in conducting technology transfer between agencies of government. There should be concern that while our society is operating on a competitive basis, it never intended government within itself to be competitive. The concept of checks and balances between the three branches of government should in themselves be adequate control and protection.

Section 6 of the Bill should include the concept of step funding of the Centers in order to allow fluctuation of appropriations to be accommodated with a minimum of damages to the host institutions or the personnel that might be involved in Industrial Technology Centers.

ADDENDUM 1.—TO TESTIMONY OF D. M. BAUMANN ON S. 1250

CENTRAL CITY, PA., *June 13, 1979.*

Prof. DWIGHT BAUMANN,
*Center for Entrepreneurial Development,*
*Carnegie Mellon University, Pittsburgh, Pa.*

DEAR DWIGHT: I have read the papers you gave me the other day and the following thoughts have occurred to me.

1. The article from the Congressional Record is a good analysis of the trend of technology in the USA during the past twenty years. However, I believe greater emphasis on the following points is warranted.

(a) The nature of engineering education has shifted from an overemphasis to an underemphasis on application during the past twenty years. At the same time University-Industry cooperation has deteriorated. This is mainly due to the increased influence of government funding agencies such as NSF, ONR, NASA, Army Research Laboratories, etc. since SPUTNIK and their lack of interest (with few exceptions) in applied research. The professors naturally shifted their interests to comply with funding agencies and their graduate students represent the majority of present day engineering faculties. It is unlikely that many practically oriented engineers will emerge from an educational system that has been persuaded it should spurn engineering design and manufacturing technology in favor of abstract analysis for such a long period of time. The net effect is that we have put a man on the moon but are losing the battle of technological innovation. The deterioration of University-Industry relation is in part cause and in part effect. At the same time funding was shifting from applied to fundamental emphasis, industrial companies were establishing their own research laboratories and were no longer dependent on help from the Universities. Today most companies feel self sufficient and are not receptive to ideas that originate outside their own organizations.

(b) Cheap capital is rapidly disappearing and greater emphasis on this should be given in planning for the future. The concept of the automatic factory while emotionally appealing, does not appear to be a sound idea when it is realized that it merely substitutes one problem for another—the problem of the disappearance of cheap labor being replaced by the problem of limited capital at reasonable cost.

2. Need exists for greater information flow to those engaged in design and manufacturing. ONR does an effective job of reporting new scientific developments in Europe by a small publication issued monthly by the London Office. This covers important conferences and University research activities for use by the U.S. scientific community. A similar service for design and manufacturing engineers should stimulate technology transfer and the generation of new ideas. A paper similar to the ONR publication covering new developments and meetings in Europe, North America and the Far East would be a useful activity of the new Office of Technology Innovation.

3. Implementation of existing know-how and techniques should receive major attention by the new office. In the area of manufacturing we know far more about what to do than is presently being used. A major attempt should be made to narrow the gap between our present state of knowledge and that being applied. Implementation probably represents a greater need today than that for more research. More short workshops covering specific ideas of technology as presented by some Universities are needed. Another technique successfully applied in Britain, until a change in government wiped it out, was the use of Vans equipped with projectors and other visual aids that enabled new manufacturing technology to be presented to workers in manufacturers' plants.

4. Funding should emphasize research by a group of companies having similar problems. Problems standing in the way of this approach which is used very successfully in Japan and Germany are:

(a) Fear of antitrust action by participating companies

(b) A tendency for large companies to force the research in an abstract direction countered by a tendency for small companies, not having independent research facilities, to force the research in an overly practical direction (solution of yesterday's and today's problems instead of those of the future). Some way must be found to protect the project director from such a squeeze play.

5. The new office should support some development work at Universities. Today, a new idea coming out of research in the University leaves too many questions unanswered for it to be adopted by industry. If funds were provided to make it possible to answer most of the questions arising when considering the implementation of a new idea, it is less likely that so many good ideas would die in the university.

6. While S1250 mentions the proposed legislation is just a beginning, it should be realized that \$60 x $10^6$ is far too little to do the job required. The problem to be solved is every bit as large as that for which the NSF was set up to solve in 1952—the overdependence of the U.S. on foreign science. Of course, NSF grew rapidly from a small beginning after Sputnik. However, let us hope that we do not have to await a similar shock in a few years to bring us to our senses relative to the applied half of our technical activity.

With best wishes.

Sincerely,

MILTON C. SHAW.

## Addendum 2.—Industrial Innovation Centres

### survey report

In June of 1978, the Honourable Judd Buchanan, who at that time held the position of Minister of State for Science and Technology, announced the Federal Government's intent to establish five university-based, Industrial Innovation Centres across Canada.

The objectives of these centres are:

1. Increase the knowledge and practical skills of prospective entrepreneurs by sponsoring the development and presentation of specialized courses in entrepreneurship and technological innovation to engineering, science, business or other degree seeking students, and short courses or workshop sessions to non-university students.
2. Provide small and medium sized technology-based Canadian companies, students, faculty, or individuals in the community with specialized advice and assistance in the technical development and commercialization of inventions and technical ideas and to help them either expand an existing business through new product or process development, or to start up a new business, and in so doing provide innovation centre students with live "hands on" experience in overcoming actual problems faced by innovators or entrepreneurs.
3. Provide innovators and entrepreneurs with a link with research and development resources resident in universities such as Industrial Research Institutes or Centres of Advanced Technology.
4. Conduct research on and become a centre of expertise in entrepreneurship, the technological innovation process and the teaching of these areas.

These centres are to be federally incorporated, and associated with, but not controlled by, a university. Control is to be vested in a board of directors, the majority of whom would be from the private sector.

As part of the Institute's role in examining the various initiatives of government in stimulating technological innovation and entrepreneurship in Canada, a survey was conducted amongst the industrial members of the Institute to determine their views on the establishment of Industrial Innovation Centres.

Written and verbal replies were received from 65% of our industrial members, with one non-member company sending in comments. of those replying, 90 percent were in favour of the establishment of industrial innovation centres as outlined above.

The following quotes were typical of many of the respondents:

"I think this is a fine idea, and a positive step towards improving R&D in Canada in a practical and small business level".

"Although I am still in the process of consulting senior colleagues, I can already say that so far their initial reception to the IIC concept is enthusiastic, as is mine".

"Basically, I think the concept of Innovation Centres is good. The idea, properly executed, can only help the Canadian situation".

"Congratulations! I am glad that at long last we are doing something at a significant level to bridge the gap between development of technological expertise on the campus and the application of that expertise in industry".

Several respondents qualified their positive support by pointing out areas in the management and organization of the centres and in the concept itself which caused them some concern.

Their main concern was with the control of the centres. Several respondents, emphasized that the centres should not be controlled by either the government or the host university. Typical comments were:

"The concept of isolating the management of the centre from both government and university must not be compromised".

"We agree that the centres should be independently operated and free from university or government control as much as possible".

A second concern was that while the centre's performance should be carefully monitored, such an evaluation should be take place before a centre has had a reasonable chance to meet its objectives. Premature evaluation could be misleading.

A third concern was that the centres would concentrate their efforts and resources on new company start ups to the exclusion of assisting existing small technology-based companies.

There was general agreement with the plan to establish the five proposed innvovation centres in stages. ("I had misgivings about the proposal until I read about the tentative time-table for opening one or two centres first, to gain some operating experience. That makes good sense")

There was also general agreement on the need for the centres to provide engineering, science and business students with specialized management training in innvovation and entrepreneurship. ("I also feel the exposure of engineering, science and

business students to this entrepreneurial training would be of long term benefit to the country").

One respondent made the important point that the design and operation of the centre should be planned from the point of view of the prospective user and not just from the point of view of the centre organizer.

The main reason given by the 10 percent of the respondents for not supporting the industrial innovation centre proposal was their belief that the centres should not be associated with a university.

In summary, the majority of respondents endorsed the establishment of two initial industrial innovation centres, separately incorporated, free from university and government control, and provided with sufficient time and resources to show that their industrial objectives can be met.

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## Annex 1

The industrial member's views of the Canadian Government's Industrial Innovation Centre proposal were based on their reading of a speech given by an official of the Department of Industry, Trade and Commerce in which he gave a brief description of the Industrial Innovation Centre Program. Annex 1 is a copy of that speech.

### Industrial Innovation Centers: Canada's Approach

(Presented by T. E. Clarke [1] at the Conference on University Research and a National R. & D. Programme, December 5, 1978, Saskatoon, Saskatchewan)

#### INTRODUCTION

On June 1, 1978, the Minister of State for Science and Technology announced that the Federal Government would be setting up five regional, separately incorporated, university-based innovation centres as part of the government's increased effort to support technological innovation in Canada. The months following this announcement have been taken up with the development of the Treasury Board submission which, when approved, gives the formal green light to the start-up of the Industrial Innovation Centre Program.

My remarks today are based on our recommendations to the Treasury Board. To-date, we have not received Treasury Board approval.

#### NAME

The thinking behind our approach or strategy towards innovation centres can be seen first in the name we have chosen for our Program: Industrial Innovation Centre Program. By using the word "industrial" we wish to emphasize to Canadians, both in academia and industry that these centres are to have a strong business theme or orientation. They should not be confused with an academic centre of study whose only output is learned papers or reports. We wish to build up in the minds of both clients who come to the centre for assistance, and students taking centre courses, the expectation that their association with the centre will provide them with pragmatic, useful skills that they can make use of in the business world. Failure to fulfill this expectation of an industrial orientation will show up very quickly and hence act as an early warning device that something may be going astray.

#### OBJECTIVE

The objectives of the Industrial Innovation Centre Program are threefold. The first, the stimulate an increase in the quantity and quality of technological innovation carried out in Canada in the form of new products or processes, or new businesses based on them, the second to make greater use of the resources contained in our university and college systems in strengthening the performance of small and medium sized Canadian technology-based businesses and in evaluating and commercializing inventions from private inventors, and third, to encourage and support the entrepreneurial activities of Canadians in their efforts to start or expand technology-based companies.

#### SERVICES

These objectives will be accomplished by the industrial innovation centres offering the following services and undertaking the following activities:

1. Increase the knowledge and practical skills of prospective entrepreneurs by sponsoring the development and presentation of specialized courses in entrepreneur-

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[1] Technology Branch, Department of Industry, Trade & Commerce.

ship and technological innovation to engineering, science, business or other degree seeking students and short courses or workshop sessions to non-university "students" The university courses, both theory and laboratory, are to be credit courses so that the students can "afford" to take them. These courses would develop the student's basic understanding of the innovation/enterpreneurship process and his skills in problem solving and analysis under real time business conditions.

2. Provide small and medium sized technology-based Canadian companies, students, faculty, or individuals in the community with specialized advice and assistance in the technological development and commercialization of inventions and technical ideas and to help them either expand an existing business through new product or process development, or to start up a new business, and in so doing provide innovation centre students with live "hands on" experience in overcoming actual problems faced by innovators or enterpreneurs.

This specialized assistance will be offered in three stages: the first stage being a preliminary evaluation both commercially and technically to identify those five or six ideas out of one hundred that are worth pursuing. This service, for which a nominal fee would be charged, will be similar to that already being offered by the University of Waterloo and the innovation centre at the University of Oregon.

The second stage would involve a more in-depth evaluation which could include a limited market or technical study. This stage would involve entrepreneurially minded students as part of their "hands on" training. The fee for this further service, which would involve some expenditure by the centre, might be a percentage of future royalties, or a percentage of stock, or bonds in a new company if the client wishes to start a company around the idea. If the stage two evaluation of the idea or invention remains positive, the client might be offered a third stage of assistance which might involve the centre investing "seed" money into the idea/invention so that it is more presentable to a venture capitalist.

The third stage assistance would include assistanting the client to prepare a detailed business plan. For this final stage of assistance, the centre would charge an additional amount in term of either a percentage of future sales in the case of the license or a percentage of stock or bonds in the case of a new company.

We do not, at this time, see the centres being a source of venture capital but simply being a link to sources of venture capital.

3. Provided innovators and entrepreneurs with a link with research and development resources resident in universities such as Industrial Research Institutes or Centres for Advanced Technology both of which were sponsored by the Department of Industry, Trade, and Commerce.

4. Conduct research on and become a centre of expertise in entrepreneurship, the technological innovation process and the teaching of these areas.

One point that should be emphasized is that the industrial innovation centres will not unnecessarily duplicate any existing local services to entrepreneurs, businessmen or inventors but will act as a local agent for such services, if that is possble. The centres will endeavour to become comprehensive assistance centres for technology-based firms or inventors.

STRUCTURE

Our thinking about the structure of the centres is not very advanced at this point in time as we hope to work out structural details with centre personnel during the preparation of a startup grant proposal.

In general, we would anticipate at least three branches to a centre, one for the course development/teaching element, one for the advice/assistance activity and one for the research/study activity. The work of one branch will obviously be coordinated closely with the activities of the other branches.

A major element in the overall structure of the Centre Program is our recommendation to Treasury Board that the five regional innovation centres be allowed to start satellite innovation centres as the need for satellite centres is established. Satellite innovation centres will enable the regional centres to extend their services to businesses, inventor or entrepreneurs located at some distance from the regional innovation centre. Each university or college based satellite innovation centre will be expected to offer most if not all of the courses on entrepreneurship and technological innovation offered at the regional centre, and provided many of the services of a regional centre, depending on local needs and capabilities.

The satellite will operate as semi-autonomous divisions of the regional innovation centre.

CONTROL

Although the industrial innovation centres must work very closely with a host university and, in particular, with the faculties of engineering, science and business, the centres will not be controlled by their host university. One important lesson we

feel that we have learned from observing the American experience with their innovation centres is that the centres should be, from the beginning, federally incorporated non-profit entities.

There are four main reasons for our insistence on this point:

1. We want the centres to have as much independent decision making authority as possible and to be free of the bureaucracies and reward structure of both the government and the host university.

2. Since the centres are dealing with business matters they should have the protection of limited liability.

3. As a separately incorported entity they are more likely to adopt a business outlook for the centre activities.

4. The centres will be free to recommend any source of assistance or help in the community or in Canada, for that matter, and not be tied to any one source.

The Board of Directors of a centre will be a working Board with most of the Directors being people who have actually gone through the process of starting a technology-based business or of launching a new product or process. Other Board members will be drawn from government and academia. It is intended that the Board of Directors will have a strong influence on the operating policies of the centre, ensuring that the activities of the centre are directed towards the practical needs of both students and industrial clients in the region.

The operating budget of the regional innovation centre will be supported by the federal government by means of a grant. The budget of satellite centres will be processed as part of the budget of the regional centre.

### EVALUATION

During the first few years of an innovation centre's life, it will be constantly monitored by the Department and by independent evaluation.

In particular, a centre's performance will be judged by the following criteria:

1. Number and sales value of new products or processes successfully developed.
2. Number of successful new businesses started.
3. Number of jobs created or saved.
4. Number of businesses assisted, with the economic results documented.
5. Number of university graduates, who have taken centre courses, involved in small technology-based businesses after graduation.
6. Number of students taking centre courses.
7. Number of seminars or workshops presented to businessmen in the community.
8. Numbers of research reports on technological innovation and enterpreneurship produced and published; and
9. The degree to which the centre is moving towards becoming self-financing.

We hope that close monitoring using these criteria will warn us of the need to take corrective action in time before any problem becomes too large.

### TIMING

Again borrowing from the experience of the U.S. innovation centres, we have decided to have a start-up phase for a centre. The start-up grant will enable the recipients to first of all undertake the detailed planning necessary to develop a work plan which will be part of their submission for an operating grant, secondly to begin the development of the centre courses, and thirdly to develop the close contacts with the business community to determine the needs and priorities of the small-medium sized technology-based firms in the region.

The size of the start-up grant can be as much as $200,000 spread over one or two years.

If at the end of the start-up phase the centre officials fail to come up with a satisfactory work plan or fail to demonstrate that they have the active backing of both the university and its key faculties, and the local business community then we are prepared to walk away. Receipt of a start-up grant does not guarantee the subsequent award of the operating grants.

Once an operating grant has been awarded, subsequent operating grants will depend on the previous year's performance. As soon as we receive Program approval from Treasury Board, we will start detailed planning for Program operation.

Our initial tentative time table is to start one or two regional industrial innovation centres in the next two years, and gain some operating experience with them before starting the remaining three regional centres. In this way both we in the Department and other prospective innovation centres can learn from the experience of the first centres.

CENTRE LOCATION

We have not yet precisely defined the criteria by which we will select the location of the industrial innovation centres. We have, however, developed some general guidelines which will give you some idea of our thinking. Selection within a region will take into account:

1. the level of interest shown by local technology-based businesses in having an innovation centre developed in the community;
2. the degree to which the university is willing to work with and cooperate with the innovation centre and its staff;
3. the degree to which the proposed location is a potential breeding ground for entrepreneurial activities as evidenced by such events as new business start ups and the availability of venture capital; and
4. the university's previous record in supporting entrepreneurial activities among its faculty and students, and in the local community.

CONCLUSION

As part of our planning operation we will be taking advantage of every opportunity to meet with industry and university representatives to get their views on how the innovation centres can both effectively and efficiently meet their objectives. Our long range expectation is that the Industrial Innovation Centre Program will result, in 8–10 years time, in a network across Canada of five regional centres together with their satellite centres which will be a major stimulus to the Canadian economy.

Senator STEVENSON. DR. MORRISON?

Dr. MORRISON. Thank you very much, Mr. Chairman.

I am pleased to meet with the subcommittee here today to discuss this very important subject of technology innovation.

In accordance with your request, I will simply state the conclusions from my prepared remarks and assume that the text will be incorporated in the record.

Senator STEVENSON. All statements will be entered in the record if summarized.

Dr. MORRISON. Before I begin my conclusions, I would like to say that I strongly support the comments made by Dr. Branscomb in his opening remarks. I especially applaud him for setting the stage to focus on the two broad aspects of industrial innovation: one involving the technology base and the other involving the business environment.

I think the essence of my remarks very much follow that same dichotomy of interests.

Now, turning to my conclusions:

First. In light of our declining international competitive position and the challenges to our technical leadership, I believe that all possible steps should be taken to expand our knowledge base and to stimulate technological innovation by industry.

S. 1250 can provide one of these steps.

Generic technology is particularly important in areas such as manufacturing, materials recovery, recycling, substitution, energy conservation, and transportation.

Second. While the principal sections of the bill deal with the establishment of centers for industrial technology, these proposed centers are similar in scope and purpose to the independent, not-for-profit research institutes which have been in existence for more than 40 years, and one of which I represent here today.

I think my model of how one approaches technological innovation is somewhat different than my colleagues on the panel here. I believe that the experience of these research institutes can be used by the Congress as well as by the administration to guide the

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formation of such centers and perhaps establish, based upon their record of accomplishments over the years, a level of expectation that one might gain from centers for industrial technology.

Third. The experience at research institutes clearly demonstrates that the process of innovation depends upon the nature of invention and upon the business environment, which is affected by nontechnological factors. At IITRI for example, magnetic recording is an outstanding example of an invention whose time was right for commercialization.

Another IITRI invention, is the in situ extraction of useful fuels from oil shale using radio frequency energy, has not yet aroused the interest of U.S. industry within our present business environment.

I would say that innovation is not predictable, even though the technology may be available.

Fourth. From additional experience at IITRI based on our contract research programs for industry and our technology transfer programs for the Federal Government, I conclude that the source of the invention or the innovative process or innovative concept is not important for the technological innovation to occur, if—and I would underscore the "if"— the user can obtain a favorable licensing position.

With regard to S. 1250, an exclusive license for a limited time may be needed to interest industry in participation in these centers for industrial technology.

What is essential is that industry be committed to support the development process in the applications engineering over a period of years with adequate funding. Industry must be involved in the research and development, must learn about the developments as they emerge, try them in their own companies and in their own operations, and make recommendations for refinements and improvements as the development process proceeds.

In our experience with industrial clients, the more actively a company participates in our research efforts, the more likely it is to adopt the innovation and carry it to commercialization.

Fifth. Let me state that the centers for industrial technology should emphasize technology transfer and applications engineering rather than research leading to new technology as their role in the process of technological innovation.

There is an abundance of technology available, especially from the Government. But there are only a few aggressive technology transfer programs attempting to get this technology utilized throughout all sectors of our economy.

Sixth. Emphasis should be given to the problems of developing or acquiring and utilizing technology for small- and medium-sized firms. We should recognize that in the small- and medium-sized firms—the innovation problem is considerably different than in the larger firms.

Senator Schmitt already expressed a concern about the lack of small industries within his own State, New Mexico, in spite of the widespread base of technology that the Government already has there. I think there is an excellent role that the centers could play in transferring the technology that the Government already has to small industries.

Seventh. Again, based on our experience, technology transfer to industry demands an extensive and intensive outreach program to acquaint industries with the opportunities that are open to them and to effect the adoption of technology.

There are some comments in my prepared testimony with regard to our efforts for NASA in operation of the manufacturing applications team that relate to this particular point.

Eight. Curriculum developments and the training of entrepreneurs in business, marketing, finance and management skills I believe are also an important role for these industrial technology centers.

In discussions with several persons in Chicago, it is easy to identify that there is venture capital available for entrepreneurs. But many of their applications are now being turned down because they lack the sound business or sound management plans.

And, finally, I believe that the centers could take a more direct role in bridging the management gap by planning for and organizing new technology-based companies. The centers could identify and evaluate the new technologies. They can prepare business, marketing and financial plans; they can recruit the managers; they can obtain the venture capital and employ management services during the startup period.

I was very pleased to hear Dr. Bauman's testimony. It sounds as if that kind of an activity that's going on at Carnegie-Melon right now. That's my old alma mater, so I feel very proud that it is.

So I think Carnegie-Mellon, perhaps, serves as another model for the role of innovation centers in S. 1250.

I would like to conclude by reiterating that I believe the problem of declining technological innovation in the United States is real. The Federal Government needs to motivate industry to revitalize its efforts in technological innovation as an important step toward our reestablishment of an international competitive position.

Thank you.

Senator STEVENSON. Thank you, sir.

[The statement follows:]

STATEMENT OF DR. DAVID L. MORRISON, EXECUTIVE VICE PRESIDENT AND DIRECTOR, IIT RESEARCH INSTITUTE

I am pleased to meet today with the Subcommittee on Science, Technology and Space to discuss the important subject of technology innovation. The apparent trends with regard to technological innovation in this country are well known to all of us. The decline in our productivity growth rates; the formation of very few small, high technology companies in the past several years; and the downward trend in the fraction of U.S. patent applications from U.S. inventors are outward signals of severe disturbance of our position in world technological leadership. Our industrial and manufacturing enterprises depend upon technological innovation and a broad base of scientific and technical knowledge as a renewable source of products and services. If foreign competition produces new goods at lower prices, our domestic industries are the ones that suffer, unemployment will increase, deficits in our balance of payments will continue, and the inflationary spiral will continue upward.

Before addressing some comments to S. 1250 and the questions raised in your invitation to participate in this hearing, let me make a few remarks regarding IITRI's experience in the process of technological innovation which will lead me to some conclusions on the nature of the process.

The IIT Research Institute is one of the largest, independent, not-for-profit research corporations in the United States. It is affiliated with a private university, Illinois Institute of Technology. IITRI operates independently of IIT and has its own full time staff dedicated to contract research, its own facilities and equipment, and its own financial statement. As a contract research organization IITRI has to

receive for services rendered sufficient revenues to cover all of the expenses. As a not-for-profit organization any revenues in excess of expenses cannot inure to the benefit of any individual but rather must be used to further its public purpose. In IITRI's case such excess revenues are used to buy advanced equipment and fund studies to expand our research capabilities.

Several examples from our multiclient programs will serve to illustrate some important aspects of the process of technological innovation. In multiclient programs many companies provide financial support and all of the participants have access to the results.

At the end of World War II computers were sophisticated tools little understood or used by industry. Starting in the early 1960's IIT Research Institute was supported by industry and government to develop APT (Automatically Programmed Machine Tools) a concept that had emerged at MIT, for industrial applications. APT was the basis for and is still commonly used for controlling machine tools.

In the late 1960's another major multiclient program emerged from the APT program on Computer Aided Manufacture (CAM). This program was conducted at IITRI for about a decade. It continues as an independent activity run by interested companies as CAM-I in Richardson, Texas. CAM-I continues to serve as a joint technical outreach by the participating companies.

Another related effort is Advance Manufacturing Methods (AMM)—a multiclient program which has been underway at IITRI for 18 years. The objective of the program is to develop computerized techniques for scheduling materials and people to optimize the productivity of a manufacturing operation. Over the years some 60 companies have supported and participated in this program. There are many documented success stories of AMM having substantial impact on company production. Commercial systems are becoming available for some of these activities and we would expect IITRI's role in AMM to phase out over the next few years.

The Manufacturing Productivity Center was established two years ago to help focus the expertise at IIT Center—IITRI and IIT and several other organizations—on the productivity problem. It is another example of our efforts in innovation. Overall, IITRI and IIT are doing $4 million dollars worth of studies relating to manufacturing productivity for a variety of companies and government agencies. Our activities include a monthly publication, Manufacturing Productivity Frontiers, with some 1000 copies distributed monthly. The Center is financed through annual membership fees. Since the effort far exceeds that which any one of the companies pay for, we expect each member company to get values far in excess of their membership fees. There are 11 member companies at present,[1] and we expect to have 20 by the end of this year.

As a final example, let me describe our efforts for the National Aeronautics and Space Administration in the operation of the Manufacturing Applications Team (MATeam). We have just completed our second year in this program.

The objective of the MATeam is to identify manufacturing problems through communication with industry and to transfer NASA technology without charge to the manufacturer. The MATeam is composed of technical personnel at IITRI who work with professional societies, industry associations and individual companies to define significant widespread manufacturing problems and identify the appropriate NASA technology as potential solutions. The team, in cooperation with NASA and industrial organizations, demonstrates solutions by conducting application engineering work. The MATeam is sponsored by NASA as part of its Technology Utilization Program which is aimed at increasing the Nation's return on investment in aerospace research by assuring that the benefits of this technology are made available to all sectors of the economy.

Two types of transfers of technology occur under the MATeam program: direct transfers in which the technology can be used to solve manufacturing problems with little or no modification, and transfers where a combination of participation and funding by industry and government is required for applications engineering. In 1978, eight direct transfers occurred and four applications engineering projects were initiated. An example of a direct transfer is use of an A-C motor power factor controller to reduce energy consumption of small electric motors. A typical project in applications engineering is the transfer of technology for a non-destructive test device that will automatically measure fracture toughness in ship hull plating. Both we and NASA are pleased with these accomplishments so early in the program even though more than 300 contacts with industry were needed to achieve this level of success.

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[1] Beatrice Foods, Bell Helicopter, Textron, Esmark, General Electric, International Harvester, McGraw-Edison, Motorola, Society of Manufacturing Engineers, Tektronix, Sunbeam Appliances, and General Motors.

Having considered these examples, let us examine common elements which are important in the process of technological innovation. The source of the invention or the innovative concept is not important. It can come from government, industry, academia or an unaffiliated individual. What is important is that there is a commitment by industry to support the development process for a range of applications over a period of years with adequate financing. Industry must also be involved in the R. & D., learn about the developments as they emerge, try them within their own companies, and make recommendations for refinments and improvements. It has been our experience that the more actively a company participates in a multiclient program, the more likely it is to adopt the innovation. The costs to the company of their own participation are many times greater than their share of the costs in the multiclient program.

Another important element is the role of the research and development organization. A successful innovation requires the collaborative efforts of many scientific and engineering disciplines, so there must be breadth of capabilities within the organization. The synergism which is possible when the organization is working on a multitude of problems, even some in totally unrelated fields, can lead to the success of a development. There must be a willingness to address the development problem in the context of its industrial application and the recognition that not all of the problems are technical. The demands of the innovative process require a full time dedication of a team of people for an extended period of time. A multiclient program may last 5 to 20 years before the technology has reached the fullness of its development and application. Transfer of technology requires a tremendous effort and a determination to follow through to achieve even a limited number of transfers.

IITRI has performed 300–500 contract studies for industry annually over the past 25 years. Over that period there have been significant changes in the mix of clients and projects. Early in that period about one-half of the projects were for medium or small companies and about 80 percent of the projects had as objectives the development of new products and services or the improvement of existing products and services to reduce costs, increase market penetration, and to increase profits for the firm. Today over 80 percent of the projects are done for large companies and something less than 20 percent of the projects are profit motivated. Over 80 percent of the industrial sponsored studies are defensive R. & D., i.e. done to satisfy safety and health regulations, minimize risks, or solve pollution problems. In addition there has been a shift away from laboratory based experimental research to analysis and evaluation studies using existing information.

Our limited sample raises a serious question—could it be that only 20 percent of today's research is going forward toward innovation compared to 80 percent a decade or more ago? From this one might conclude that in fact we are doing only 25 percent as much innovation bridging R. & D. as we did a decade ago. Also distressing is the withdrawal of the small and medium companies from outside R. & D. purchasing. Could it be that they are trading the future for the "now" problems of pollution control, health and safety?

I have presented this background on R. & D. at IITRI as further evidence that the problems of technological innovation are real. IITRI's history, I believe, is a good reflection of the R. & D. trends in the United States. The changing patterns in R. & D., which precede by a few years the changing patterns of technological innovation, are the result of a complex set of political, economic, social, and institutional factors. Together these fators have produced a business environment where risk taking is low and guarantees in the success of R. & D. and technical innovation are required before projects are launched. Product safety must be assured, plant effluents must be controlled, and capital must be invested to survive in present businesses rather than to innovate and invest in replacement of our technical obsolescence. Our foreign competitors are willing to take risks less encumbered by environmentalists, anti-progress groups, and governmental regulations. They are stimulated by favorable treatment on taxes, investments, and antitrust regulations.

The United States, for a variety of reasons, seems to have lost much of its ability to innovate. Unfortunately our basis of comparison is the two decades following World War II where the United States dominated technological innovation. During these post-war years we saw developments such as television, computers, transistors, lasers, jet aeroplanes, nuclear power, space satellites, lunar landings, and antibiotics. There is ample reason to question whether such a pace can be sustained indefiniately. However, we have reached a low point in innovation and have given ground to our international competitors. Somce examples will help to illustrate this point.

Computer aided manufacture, especially numerically controlled (N/C) machining, is an advanced manuacturing technology which would appear to be capable of

impacting significantly on manufacturing productivity. N/C machines were conceived and demonstrated in the U.S. Nevertheless, a recent study showed that U.S. industry purchases fewer N/C machines as a percent of total machines procured than any other industrial nation. The acquisition and application of this technology to U.S. industry is not progressing at a sufficient rate to reverse our declining productivity growth. Small firms have been reluctant to adopt this technology. Aside from general market factors and costs, the small manufacturers are unable to test in an objective way the use of the new techniques on their products independently of the vendor. It is also difficult to measure the indirect benefits of automated equipment, such as the value of flexibility, to a small firm.

The basic oxygen furnace (BOF) was invented and demonstrated in the United States. In spite of this U.S. invention, Japanese steel makers introduced and used BOF in steel making before it became standard in the United States.

Processes for production of liquid or gaseous synthetic fuels are examples of overseas technology that have been demonstrated and at least limited commercialization exists. The U.S. can obviously buy this technology but it is likely to be many years before the United States will commercialize its competitive technology.

In the transportation sector, foreign automobiles are making major inroads in domestic sales through innovations to achieve fuel economy. The City of Chicago has turned to foreign manufacturers for articulated buses, an innovation to increase the number of passengers per vehicle and still be able to contend with narrow congested streets.

It is apparent that the Senate has recognized the severity of the problem and through S. 1250 seeks to enhance technological innovation in this country. The establishment of centers for industrial technology will serve as a reminder to industry that technology and technical innovation are important to business. The enhancement of innovation through the development of the generic research base is particularly important. It has been our experience at IITRI that industrial firms are willing to invest in research when they have an immediate need. Smaller firms, in particular, are less willing to invest in the building and maintaining of a base of technical knowledge which can be called upon when solving problems or making innovations. Small firms play an important role in our economy. As suppliers to the larger firms, as well as producers in their own right, their productivity and technical innovation are critical pacing elements in our overall national well being. In the legislation it might be desirable to give additional emphasis to the undertaking of R. & D., education programs, and information dissemination for small companies and industries.

The provision of funds for research and development also provides the were-withall to the one essential element in the innovation process, the inventor. Experience again shows that not all researchers are inventors but that the few that are produce numerous inventions. If the R. & D. funds can be used to support these creative people in a framework that is structured to benefit an industry or collection of industries, and if these funds can be made available to demonstrate proof-of-principle, the chances of reversing the trend of technological innovation are high. Invention and the demonstration of the workability of the invention to industry are major steps toward incorporation of technological improvements in the industrial process.

Requirements for cost sharing in the support of the technology centers, by virtue of the fact that only 75 percent funding can be obtained from the federal government, will improve industry's acceptance of the results of the Center's efforts. Early commitment to the technical innovation process will be assured by this requirement. Funding by industry also helps eliminate the concern that free technology is not useful. Our experience is that which is funded is more likely to be considered seriously for further development.

The patent and licensing arrangements proposed in S. 1250 will help to eliminate the reluctance of industry to participate in the development and application of technology also supported by the federal government. The possibility of acquiring an exclusive license even for a limited period of time should be attractive to the entrepreneurial interests of a firm, protect their investments in the critical stages of development, and permit them to establish an early position in the market.

The bill does not deal with the duration of grants. Multiple year, preferably 5 year, grants should be authorized for the establishment of the technology centers. Grants of this duration provide stability in operations and the means to attract and hold key staff. In addition, continuity in research programs is important if innovation is to occur. However, the time must not be too short or all of the companies will wait to be the second on in the market place.

S. 1250 directs that one of the activities of the Centers for Industrial Technology be curriculum development and instruction in invention, entrepreneurship, and industrial innovation. This activity is important and fulfills a current need. For

example, Stanley Golder, President of First Capital Corporation of Chicago and the National Venture Capital Association, states that "many applicants for venture capital who have promising new inventions, are turned down because they are lacking in sound business, marketing, and financial plans, and a managemnt team * * * There is substantial capital available nationally for new ventures in which the relationship between prospective return and risk is judged to be favorable." This current gap between invention and the corporate skills supportive of the innovation process can be met in part through educational programs. While one cannot be trained to be an inventor, the education in the management of technological innovation can be an important role of the Centers.

Many universities now provide courses in general entrepreneurship. However, education programs administered by the Centers will specialize in entrepreneurship based on technological innovation. The educational experience of students in these programs will be greatly enriched by involving them in various Center activities.

In addition, the Centers could take a more direct role in bridging the management gap by planning for organizing new innovative, technology-based companies. Center staff members expert in appropriate areas could seek out and evaluate new technology, prepare business, marketing and financial plans, recruit managers, obtain venture capital, and provide management services during the start-up period. In this way the Centers could directly accelerate the movement of new technology into the market place.

In conclusion, let me reiterate that the United States problem of declining technological innovation is real. Our country's economy has been built by entrepreneurs utilizing technology. The enactment of S. 1250 will rekindle technological innovation and will be an important step toward the re-establishment of our international competitive position.

Senator STEVENSON. Prof. Nam Suh.

Mr. SUH. Mr. Chairman, I would like to submit written testimony for the record and I would like to just make a few comments.

Senator STEVENSON. Please do.

The statement will be entered in the record.

Mr. SUH. I will be very brief.

Since 1973, we have been conducting a cooperative research program entitled the MIT-industry polymer processing program. The program has been established for a number of different reasons, and I think this committee may be interested in knowing why we started the program.

Polymer engineering, as such, is a very important field, because today we are using more polymers in weight than all in nonferrous metals combined and perhaps more polymers than steel in volume, and yet many universities have not addressed the issue of educating our students in this important engineering field.

We felt that MIT should assume the leadership in educating our students in polymer engineering and particularly polymer processing, which was the area I was interested in.

We were hoping that other universities would also initiate this kind of educational programs based on the example set by MIT, because all universities have the problems in initiating new studies and new educational programs, because of institutional inertia. Sometimes it's very difficult to establish a new academic discipline because of the lack of educated people who can teach a new academic subject.

The second reason MIT initiated the program was that the innovation process and the creative aspects of engineering have not been taught effectively at universities, since the traditional instruction at universities consists of analysis rather than synthesis. We wanted to teach our students how creative engineering is done through realistic problems that only industry can supply to academia. Through this interaction with industry we thought that edu-

cational institutions can depart from their traditional thought processes.

The third reason for the cooperative research program was that we wanted to increase the interaction between MIT and industry. Even today, notwithstanding our effort, MIT depends a great deal on the Federal Government's support for research; 95 or 96 percent of the MIT's research support is coming from the Federal Government and only a small fraction is coming from industry. We believe that this heavy dependence of universities on the Government support is a very critical issue for us to address, because it tends to bias our educational processes in favor of problems oriented toward the public sector vis-a-vis the private sector. This is another reason we wanted to increase our interaction with industry.

Fourth, we identified the polymer processing field as the right area for cooperative research because the industry is highly fragmented consisting of many small companies. The highly fragmented industries are unable to undertake basic research and cannot provide the kind of innovation that is needed for their growth and viability.

These are the four reasons why we started this program. I am happy to say that we have at least demonstrated that these goals are realistic through the experiment we have performed with the MIT-industry polymer processing program during the past 6 years, which is now entirely supported by a consortium of industrial firms.

One of the major goals of cooperative research is to realign institutional relationships so as to use the resources available at various differing institutions to a maximum extent. This bill 1250, I think, will go a long way in helping us strengthen institutional relationships. But there are inherent barriers that I think this committee should be aware of. One of these barriers is the attitude of people in industry and in academia. The people in industry often do not feel that the people in academia can solve the problems of industry; some academicians, on the other hand, feel the kind of industrial problems they have to work on will not be intellectually challenging and therefore they should not tackle industrial problems.

These are real problems that we are facing today.

One of the things we have tried very hard to demonstrate at MIT during the past few years is that indeed one can address industrial problems and at the same time do significant basic research. We have explored a number of basic research areas and have made substantial contributions to the industrial effort of our cooperating member firms. In short, we have tried to eliminate the myth that universities and industry cannot cooperate.

In order to make this kind of cooperation work there are many elements one has to consider. One of these elements is the maintenance of the integrity of all institutions involved. There have been suggestions made by some that industry should dictate the university research, but I believe that it is wrong just as the university should not tell what industry ought to do. And I feel that this matter of maintaining institutional integrity is one of the major issues that we have to consider in establishing cooperative research programs.

I think the university must be free to pursue its stated goals: education of people, exploration of new ideas, determination of the cutting edge of knowledge and maintenance academic freedom. I think these goals are very important for universities.

Industry, on the other hand, should be allowed to pursue their profit motive, while the Government's role is to has to protect the public interest.

The institutional integrity issue, I think, is one of the issues we do not discuss enough in a public forum, but I believe that without maintaining institutional integrity, cooperative research will not be a viable concept on a long-term basis.

Another important element to consider in establishing industry—university cooperative research centers is the matter of technology transfer. Unless we promote technology transfer, these centers will not survive since they will not have adequate industrial funding.

In order to facilitate technology transfer, I would like to suggest that all the participating industrial firms make a substantial financial commitment to these centers. Without the financial commitments industry will not commit the time, the personnel and the effort required to transfer technology from the center to industry. And, in this sense, this bill can be strenghtened a great deal if the bill can stipulate the financial commitment of the participating industrial programs in more definite terms.

In order for the centers to be successful, the participating industrial firms must have significant financial incentives. I would like to suggest that the bill allow the distribution of the royalty to the participating industrial firms in proportion to their support of the center after the center retains a certain fraction of the royalty income. Without such incentives it would be very difficult for these companies to give to the center the kind of information they need to establish meaningful research projects, because nonparticipating companies may benefit as much as the participating companies. I think that kind of additional incentives is an important element in justifying industrial participation in cooperative research.

Another important element that we ought to consider in making the center successful is the long-term financial commitment of the Government. The funding should not be given on a year-to-year basis. Each center should be given 5-year funding at least, so they can find the best ways of operating the center and find their own niches in dealing with industry and Government.

I would also like to comment on cooperative research in Germany and Japan. I don't think we should emulate the German and the Japanese experience in this field, because their given conditions are substantially different from ours. Japan and Germany, all these years, have more or less tried to refine existing technology rather than innovate new technology. They have not been innovators and, indeed, Americans were the innovators. I think we should maintain that tradition as well as doing a better job in maximizing the benefits from the existing technology.

Therefore we should be very innovative about this bill and come up with the kind of institutional relationship that will work in the surroundings that we find ourselves in.

Finally, I would like to close my statement by saying that we should capitalize on the experience the National Science Foundation has gained in cooperative research during the past 6 years, instead of creating a new major Government organization. I believe that there is yet a great deal to learn about how to promote better institutional relationships in this country by experimenting with different kinds of concepts, rather than institutionalizing a system at this point.

Senator STEVENSON. Thank you, sir.

[The statement follows:]

STATEMENT OF NAM P. SUH, DIRECTOR, LABORATORY FOR MANUFACTURING AND PRODUCTIVITY, AND PROFESSOR OF MECHANICAL ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

In 1973, the Massachusetts Institute of Technology established a cooperative research program entitled the MIT-Industry Polymer Processing Program as a means of enabling the student to experience the innovative aspects of engineering and as a means of increasing the interaction between MIT and industry. The Program was made possible by seed funds provided by the Experimental R. & D. Incentives Program of the National Science Foundation. The Program is now fully supported by a consortium of industrial firms and has an annual budget that exceeds the entire support received from NSF over a five year period.

Our experience with the Program has demonstrated to us that cooperative research programs can indeed strengthen MIT's educational process, assist industry in meeting some of their short- and long-range needs, and stimulate the thought processes involved in technical innovation. Perhaps the most important lesson we have learned is that the realignment of institutional relationships can indeed yield rich dividends in terms of more effectively utilizing existing resources, promoting synergistic interaction of people and ideas, and facilitating technology transfer. As a result of our cooperative research program, we have developed many new processes, a number of which have resulted in patents.

In view of the positive experience we have had with the MIT-Industry Polymer Processing Program, MIT has established two new cooperative research programs with internal funds. We are also planning to initiate several more such programs.

Based on my experience as the Director of the MIT-Industry Polymer Processing Program for the past six years, I believe that the goals of the Senate Bill S. 1250 are sound and timely. The Bill, once enacted, should provide us with the necessary institutional framework within which to pursue generic research on a cooperative basis in many areas of technology. However, some aspects of the Bill need further analysis to ensure the successful achievement of the stated goals.

I believe that there are several important and necessary elements which must be considered if cooperative research programs are to succeed. A review of these elements may assist the Committee in isolating those aspects of the Bill that require further attention.

First, the new relationship between universities and industry must assure the maintenance of institutional integrity among the groups involved. Educational institutions must be able to retain academic freedom and pursue their academic inquiry in a manner consistent with their educational and research goals; industry must be able to pursue its profit motivated goals to ensure adequate return on their investment; and the government must protect the public interests. That means that no one group, be it academia, industry or government should be able to dictate terms to the rest. In this sense, the Industry Technology Review Panel should comprise a balanced representation from industry and academia.

An important elements in setting up self-sustaining cooperative research centers is the establishment of mechanisms for technology transfer as an integral part of the charters of the centers. In order for technology transfer to occur, key people from cooperating institutions must be committed to the centers' activities. The best way of guaranteeing the involvement of key industrial people is for the participating industrial firms to make significant financial commitments to the centers' activities. Once the financial commitments are made, the management of the participating firms will allocate the time, personnel and effort required to share equally the responsibility for technological success and effective technology transfer. Therefore, it will be desirable to have in the Bill a more specific stipulation regarding the financial commitments industrial firms must make to participate in the centers.

The technology transfer process requires that the participating industrial firms have sufficient financial incentive and the prospect of a reasonable return on their investment. In this respect, I would like to recommend that the royalty income generated from patents be returned to the participating industrial firms in proportion to their support, after a center retains a certain fraction of the royalty income. In many instances, royalty-free, nonexculsive license is not sufficient incentive for participation in cooperative research especially if significant financial commitment is required.

I also believe that for a cooperative research program to succeed, there must be, from the beginning, definite long-term financial support by the government with a minimum of government control. The centers should be allowed to find their own niches as long as the participating firms and the center management agree on their course of action. In this respect, the Bill can be strengthened a great deal if it specifically states that the government will not have rights to patents generated as a result of the work done after the termination of government support.

In recent years, we have heard a great deal about institutional relationships in other countries. It is clear that some of the other industrialized countries have paid a great deal of attention to this issue in order to maximize the synergistic interaction among various groups. We should learn from their experiences. However, I feel that such information must be evaluated in a proper context, since we cannot simply emulate the German and Japanese institutional relationships. Their given conditions are quite different from ours, especially in that they were more refiners of technology than innovators of new technology. We must continue to be innovators and do an even better job of developing the most advanced technologies if we are to maintain our standard of living. Thereore, we must formulate our own best relationships that are compatible with our financial, legal, technological and educational structures.

Finally, I would like to close this testimony with two observations. First of all, the funds allocated to the centers may not be sufficient to deal with many generic technological problems. Secondly, I would like to urge you to create simplified governmental procedures dealing with the establishment and monitoring of the centers. In this sense, I question the need to create a new office in the federal government when there are offices within NSF which have dealt with cooperative research in the past. It seems to me that we can achieve the intended goals of the Bill by relying on the experience gained during the past six years.

I would like to thank Senator Stevenson, and the members and staff of this committee for asking me to testify on this important and promising Bill.

Senator STEVENSON. Dr. Udell.

Dr. UDELL. Thank you Mr. Chairman.

I am Gerald G. Udell, director of the innovation center at the University of Oregon.

The Oregon Innovation Center differs from its sister centers at MIT, Carnegie-Melon and Utah, in that it is located in a business school in a liberal arts university which does not have an engineering school attached to it.

I have been involved in outreach programs in the university environment for about 10 of the past 12 years; 2 years in a small business-consulting capacity in an EDA-funded center at the University of Wisconsin in university extension.

Half of my Ph. D. is in the area of extension education and, more recently now, 5 years after the innovation center at the University of Oregon.

When I received your letter asking that we limit our remarks to about 10 minutes, you precipitated somewhat of a crisis by asking an academic to summarize 10 years in 10 minutes. I want to thank Senator Schmitt for providing me the key that I have been looking for, as to how to do it. He used the word "balance," earlier today, and that's the focus I would like to use here in looking at these centers.

I would like to discuss first the mix as I perceive these centers.

First, I think the centers have the mission to do research. This research has to be balanced and it has to be an appropriate combination of both basic and applied research.

I also perceive that the centers have a mission in the area of education, combining both traditional and nontraditional education in a balanced way.

Finally, I perceive an outreach mission for the centers combining a technology-based outreach program with a commercial management assistance based program in a balanced function to insure that the incentives are applied throughout the innovation process and are not limited to just the early stages of that process.

If I remember the Booz, Allen & Hamilton data correctly, R. & D. costs represent only about 30 percent of the cost of bringing a new product, process or service to the point of commercialization. The rest are costs that are commercially oriented. And I think these centers need to recognize this and not be just technically oriented, but also to be commercially oriented.

There is need for involvement on the part of business schools and other schools, as well as the technology oriented schools.

Also, I think there needs to be a balanced approach to providing incentives and that these incentives should incorporate both large and small businesses. The legislation as currently written tends to steer universities in their natural direction toward large corporate involvement.

I urge the committee to consider specific involvement of small business.

I think the data indicates that we are behind in terms of technological innovation, but that there is not single segment of the economy that is responsible for technological innovation. Consequently, no one is specifically responsible for the problem.

I hesitate to place the problem at the feet of the corporations, solely. I think we all share that responsibility. Consequently, we all share in the responsibility for stimulating innovation, and I think we ought to stimulate innovation, whether it covers small business, large corporations, and universities, or what have you. I think the program needs to be balanced in terms of Government, university, and private sector involvement.

I do not perceive that the universities or that these centers should necessarily have as their objective, total self-sufficiency. If you do this, the centers may focus on becoming self-sufficient rather than trying to solve the technological problems facing society.

On the other hand, the centers should not be so comfortable in their position that they have become stagnant. There should be an incentive. There should be a built-in requirement, if you will, that they become involved with the private sector.

Earlier we talked about the cooperative extension service. I think one of the reasons that the cooperative extension service has been successful in terms of application is because it has involved the private sector. There has been involvement at the local level, at the county level.

Also, one final point. In terms of this concept of balance, I think there should be a balance between starting new ventures, working

with existing ventures, and also providing the opportunity for technology transfer.

In the latter area, there are many inventors of an unaffiliated nature. These include the traditional inventors or grassroots inventors, plus technological inventors who have fertile minds and are a good source technology. These people have no desire to stimulate or to generate new business and so there is the problem of transferring an idea from the inventor to the innovator, technology transfer programs have to take into consideration both existing corporations, new ventures, existing business of both a large size and small size.

With that, I will conclude my remarks.

Thank you.

Senator STEVENSON. Thank you, sir.

[The statement follows:]

STATEMENT OF GERALD G. UDELL, PH. D., DIRECTOR AND ASSOCIATE PROFESSOR, INNOVATION CENTER, UNIVERSITY OF OREGON

During the past five years, I have been the director of the University of Oregon Innovation Center. This Center, along with sister-Centers at M.I.T. and Carnegie-Mellon was established by the National Science Foundation in 1973 as part of an experiment to test incentives for stimulating industrial innovation. The Oregon Innovation Center differs from its sister-Centers in that it is located in a business school in a liberal arts university with no engineering school. The Oregon Center is perhaps best known for its program for unaffiliated and small business inventors and has provided evaluation and other assistance to nearly 5,000 inventors from throughout the United States.

I am appearing in supports of S.1250, the National Technology Innovation Act of 1979.

While there may be some question about the extent of the alleged decline in the rate of technological innovation in the United States, the fact that industrial innovation is not keeping pace with the social, economic, and environmental needs of this nation is obvious to all of us. Incentives to stimulate needed technological innovation are urgently needed. S.1250 provides an appropriate format for one such incentive.

In addition to the following remarks, I have furnished the Committee with two papers; the first of which examines the concept of coupling industry and university to stimulate technological innovation and the second of which analyzes S.1250 in some detail. Since my specific concerns with the legislation before this committee are outlined in the latter paper, I shall limit my remarks here to some of the operational issues and to the questions contained in Senator Stevenson's letter to those testifying here this morning.

Senator Stevenson, in introducing S.1250, presented an accurate picture of the seriousness of the decline in industrial innovation. He was also correct in stating that "we cannot quantify or describe in any rigorous way the state of the U.S. industrial technology and innovation." Good data just simply isn't available. S.1250 will help remedy the situation by:

1. establishing an Office which will have as a major mission, research oriented toward developing a better understanding of the industrial innovation process; and
2. providing for university-based Centers which can aid the Office in generating the data necessary for more effective policy-making.

Without a concerted effort such as proposed in S.1250, time is not likely to improve our comprehension of the Innovation Process.

Moving on to the second question raised by Senator Stevenson, I find that on the whole, university-industry relationships are good. At the Oregon Innovation Center, we have experienced little difficulty in relating to industry. We have, however, experienced some difficulty in relating to the academic community. This is partially because of the experimental nature of our program, but also because of some conflicts between the nature of our mission and that of a university.

Universities do have the interdisciplinary resources necessary for industrial innovation. They are capable of generating new ideas with high commercial potential, conducting research and development, training entrepreneurs, and providing technical and commercial assistance. In my mind this is not the question. Rather, it is one of: "Will they?"

Given the current state of university finances and a widespread commitment to basic research, the university willing to make a significant contribution to industrial innovation is more likely to remain the exception rather than become the rule. Adequate funding over an adequate period of time is an absolute necessity.

However, funding alone will not insure that universities will fulfill the role envisioned for them in S.1250. To some universities, industry involvement, applied research, and technical and commercial assistance are the antithesis of the true function of a university. Others may be willing to permit such activities, but will not afford faculty that do, full academic honors. Faculty reward and tenure policies frequently work against such involvement. At most land-grant schools, this problem has been resolved by establishing separate standards (but not necessarily equal status) for applied or extension faculty.

Few university systems have reached a level of maturity where applied research and outreach have been integrated with traditional teaching and research missions. This does not negate the validity of S.1250. It does mean, however, that not all universities are viable host institutions for the Centers proposed in S.1250.

It also means that this program will require skillful administration and careful planning at both the federal and university levels. The implications here are several:

1. The director authorized in subsection 5(b) must be knowledgeable about the workings of universities as well as being knowledgeable of government, industry, and the industrial innovation process. He or she will be a key person—one who should be appointed with the advice and consent of the Senate.

2. Requirements for Centers such as those outlined in subsection 6(c) need to be established.

3. Universities must devote considerable effort to the developing program plans as authorized in subsection 6(d); and

4. Universities make a diligent effort to commercialize and develop technology as indicated in subsection 6(e).

The programs established by universities must go beyond basic research, traditional education, and exclusive involvement with large corporations. They must engage in aggressive programs of applied research, offer non-traditional innovation-related educational opportunities and be capable of providing both technical and commercial assistance to all segments of the private section of—including unaffiliated technological inventors, entrepreneurs, and smaller enterprises, as well as larger corporations.

This program must not be permitted to ignore unaffiliated technological inventors and innovators. Independent inventors in particular have been ignored by government policy, subject to public ridicule and preyed upon by unscrupulous operators. They, along with the nation's smaller enterprises, continue to be a viable source of technological innovations and deserve better treatment.

S.1250 in it current form will not insure this. Universities tend to be large corporation-oriented and without specific direction to the contrary, will move toward basic research-oriented joint programs with large corporations. I am not opposed to either basic reseach or joint programs with large corporations. Both are needed, but so is technical and commercial assistance to individuals and small enterprises.

The experiences of the Cooperative Extension Service, the University Center Program, the Small Business Development Centers Pilot Program, Experimental Innovation Centers, and the Cooperative R. & D. Centers provide valuable insights into the arrangements and requirements necessary to insure effective implementation of this legislation. These programs have tested or had experiences with many different institutional arrangements that will be necessary to build an effective program. Their experiences should be utilized. In addition, cooperative programs should be established to insure that inventors and innovators of small-scale technologies are afforded encouragement, education, and assistance.

With clarification of the issues addressed here and in my previously submitted written testimony, I believe S.1250 to be effective foundation upon which to begin to launch an attack on the declining rate of technological innovation.

Senator STEVENSON. Dr. Branscomb distinguished between basic research and generic technology and the proprietary work. If generic technology is to be a major, primary responsibility of these centers, how do you determine which? Professor Suh, you said the polymers.

Mr. SUH. Well, the question is—if I may restate your question, the question is why we chose polymer engineering, what kind of special research projects we undertake and why?

Senator STEVENSON. Well, let's settle for that, temporarily.

Mr. SUH. All areas of polymer-related topics have been developed primarily by polymer scientists in the past, and when I was in industry I realized that the engineering basis on which to deal with polymers was lacking. There are certain things that can be done only with engineering disciplines.

My colleagues here may not agree with me on this topic, but as far as I can see, the attempt to trying to draw a very fine line between basic research and applied research, I do not really feel, is valid.

Let me give you an example of why I say that. Major developments in science were made because, again, somebody had very innovative ideas. It's not as if science was developed because someone said, "Let's develop science." If you look at all the basic laws of nature we are using now to solve technological and scientific problems, many of them are axioms somebody established based on the observations they made of nature. It took curiosity, need and a stroke of genius rather than necessarily a great deal of investment to develop our understanding of nature.

I would like to clarify what I mean by the statements I made. If we examine at the type of research presently conducted in surface-related phenomena, for example, catalytic effects, the kind of things people are doing today, in my opinion, is unlikely to lead us to a real basic understanding needed to advance this field. For that field to develop, I think someone has to come out with a real innovative insight as to what governs surface phenomena. When you attack that kind of problem, then sometimes it's very fruitful to look at the real live problems they're having in industry to gain the necessary insight.

In essence, that's what we do at MIT. We are working on about 25 research projects as part of the cooperative program in polymer processing. About half of the projects were motivated by basic questions and the other half were initiated because of clear industrial needs. In many cases our attempt to understand real industrial problems lead us to very basic science areas, in which our students had to perform significant research to produce acceptable theses.

I'm not sure if I'm answering your question, Senator, but it seems to me that we are sometimes trying too hard to separate from which direction one ought to start research. My personal view is that you can start the search from any starting point as long as you have a creative mind and the skill needed to pursue the problem in a logical, systematic manner. This way, we not only create industrial technology but also make contributions to the field of science.

Senator STEVENSON. Anybody else want to take a crack at that question?

Dr. MORRISON. Mr. Chairman, I might comment briefly from the experience at IITRI as well as the other research instititutes.

This problem of whether support should be given to a generic technology or whether it should be given to basic research, is one

that I think we have effectively let to the decision of industry for a number of years. It occurs through what we would call multiclient sponsored program. We continually maintain a market development effort with industry to try to acquaint them with the kinds of technology that may be available to them, and the sorts of services which an organization like ours can offer. We do get support for very specific kinds of development programs which may be either basic or quite company-oriented.

On the other hand, through the multiclient program we develop generic technology and the results are made available to all the participants.

In our institution, for example, we started out with the APT program—the automated programed tools—which used technology originating at MIT. The technology has gone through a number of evolutions and programs through advanced manufacturing methods—AMM—which is still active, and the REAPS program, which is applying this kind of technology right now in the shipbuilding industry. Generic technology has been developed for two principal applications: numerical controlled machines and computer aided design. The technology is not proprietary and it benefits all the industries involved in the manufacturing. In total we have had more than 100 companies participate in this over a 20-year period.

Currently, we're trying to interest the industry in the use of lasers as a means to improve some of their industrial processes. Some of this research will be approached from a generic base, although we do have contracts from some industries in very specific areas of interest to them.

At least from our standpoint, we let industry make this particular decision on the nature of the technological development rather than trying to force a solution upon them.

Senator STEVENSON. Any further comment?

[No response.]

Senator STEVENSON. The concern which occurs to me is that the linkages we're envisioning here could lead toward choices given by industry and that these choices are going to be short-term commercial choices. I think Professor Suh made a very sound statement, but wouldn't you be concerned about processes such as that which Dr. Morrison described at MIT of these relations which are funded by 5 percent, you say in your case, developing to a larger extent, with far more money, proportionately more money?

Mr. SUH. Well, it depends on how we set up the projects and how students generate their master's and doctoral theses. The theses produced the cooperative research program do not differ from other theses produced at MIT. Perhaps I can clarify the statement by describing the process of project selection. Our member companies—there are 12 of them at this time—some very large, some very small. In fact, you might say about half of them are small and the others are large. They make suggestions as to what kind of things would be of interest to them on a long-term basis or short-term basis. They just give us a long list of research topics we might work on. Typically, the list contains about 20 different research projects they'd like to see us work on. Based on those suggestions, we take a great deal of time and effort to discuss them at meetings between MIT staff and the representatives of our industrial

member companies. At first on a one-to-one basis, and later on on a collective basis we discuss whether or not the suggested topics are worthwhile for us to pursue.

However, the final decision as to what kind of projects we would like to work on, how we approach it and so forth, are entirely decided by MIT. We decide whether or not certain projects are worthwhile to work on. Indeed, in some cases even when our industrial members think that what they are thinking is exactly correct, the ultimate decision is made by MIT. We insist on the final decision.

More than a half of the projects we work on were decided by MIT, although none of the member companies suggested the ideas to begin with. What we are really doing is deciding from MIT's point of view whether or not certain topics are going to have a long-term relevance to both industry as well as to academia.

As a result of this kind of effort, our student's thesis work result in publications in a number of leading scientific journals, as well as patents. In fact, many of our students have the distinguised record of not only being the author of published papers based on the doctoral thesis, but also possessors of one or two patents issued as a consequence of their doctoral or masters thesis work.

So, what we have done is that we have worked with industry to define what are the real problems and then work on them to produce the kind of scientific work that has relevance to industrial needs.

Sometimes we fail, but in many cases we have succeeded.

One thing that might be quite useful to the committee is that often in this kind of discussion we assume that we know what the problem is. On the contrary, we find that a major function of cooperative research is finding out what the problem is. In many cases we find that if we know what the problem is, there is a solution. Often what people think is a problem is not the real problem. We find that the problem was not what the people thought was the problem only after a great deal of research. A solution to a problem can only be found by defining the problem through research.

Senator STEVENSON. Senator Kassebaum.

Senator KASSEBAUM. Thank you, Mr. Chairman. I would like to complement you on taking the initiative in this extremely important area of technological innovation. Much of the improvement in our standard of living in this country has been based upon the use and production of new technological products and processes.

I believe that this country can permanently retain its world leadership in innovation, while protesting the public health, welfare, and safety, if we do not stifle the productive spirit of the individuals, universities, and companies in this country. Inventions and new ideas will never reach the public unless the private sector continues to take the initiative in commercializing those goods. As witnesses during this committee's past hearings have indicated, Government regulations and other policies have all too often discouraged innovation by the private sector.

One question I would have for anybody would be: If you were designing a program in which you were trying to stimulate indus-

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trial innovation, what would you consider the key element of this program? Would it be financing? Would it be tax incentives?

Mr. BAUMANN. I would like to address that, because I have been thinking about that for a number of years. I had been active in starting about 40 companies, 30 as an assistant in various ways and 10 in our new center, and 2 of them in which I was involved as a principal.

The basic answer is, to stimulate innovation we must develop more innovations and entrepreneurs. The most basic task, assuming a thruput of undiverted, creative people, is to deal with the issue of integrity. I'll elaborate from the story of the two shopkeepers—one who works hard all day and sweeps the floor afterwards, while the other goes home early. The hard worker finds a $20 bill, and thus arises the question, "Should he tell his partner?" That's important from the point of putting together people in organizations. It turns out if both of them would tell their partner, they would work well together; if neither one would, they also will. If one would, and the other wouldn't. The the grouping won't work out. The point is that the organization that one is putting together—and it always includes people—has to do with each other on a "face-up" basis, first of all.

Second, they have to deal with themselves on the basis of knowing when to move forward and when to quit. Entrepreneurs are usually the kind of people who appear to make big strides. They have an ego involvement in their idea. They have to also know when to quit, and when to have another idea. Hopefully they have alternatives already built into their basic approach. So they have to be honest with themselves and know when to change course.

We need to develop ways to teach people to recover from failure. Most successful entrepreneurs are successful after they have failed and recovered from the failure. We need an educational environment in which they can make a sequence of nonfatal mistakes. This, in fact, could be a university type environment. It's usually not, because university professors are people who are always academically successful and always get the right answers. Entrepreneurs get different answers.

The entrepreneurs are, often those who do not appear to fit in the university environment. They are the kind of people who will study at Harvard until they have learned as much as Harvard can teach them, like Edwin Land did. It wasn't Harvard's fault or Edwin Land's fault, but there was nothing more he needed that Harvard could provide for him. They are organized around a different concept.

I think most of our universities are organized under a different concept and probably the wrong one.

As Drucker points out, we have three kinds of people: those who make things happen; those who understand what happens; and those who wonder what happens. The latter two categories are the predominant members of our society. I think the ones who make things happen do so in spite of our present institutions.

Thus we need a mechanism where those people who can make things happen can get sustenance from each other—an art colony, studio effect. And that, in fact, is what the incubation centers at Route 128 and at Palo Alto are all about.

Dr. MORRISON. I would like to address another comment to your question, Senator. If I were designing the program, I would start with an emphasis on the aspect of innovation that deals with the business environment.

In discussions I have with people within small businesses, I've raised the question about the use of more technology, and the fact that technology can increase productivity and lead to higher profits. And the answer usually is that maybe technology would be helpful, but there are too many other pressing problems. It might be a maintenance problem on the shop floor because the equipment isn't fully depreciated and can't be replaced. Or maybe it's a tax issue that can't be dealt with. Or it's an EEO or OSHA issue or just the general pressures of the business climate.

I must admit that I don't have the wisdom to structure such a program. But it seems to me that the business climate is not one conducive to the risk of an investment in technology to improve productivity. So I would try to structure a program starting with the environment, rather than from a technology basis.

Senator KASSEBAUM. Well, along in that vein, then, would you see it as a function of the Office of Industrial Technology in the Commerce Department as being also perhaps one that would review and have an oversight function of the regulations and tax policies that may be an impediment to innovation? Do you see this as being a function that could perhaps be important and one which should fall under that office?

Dr. MORRISON. Yes; I would very strongly endorse that as a set of functions the office should have. I think Dr. Branscomb touched on the same subject in his remarks and he recommended that the Department of Commerce have all of the interests of industry and technology associated with it. There is an analogy in Japan, the ministry for industry and trade, which has, as I interpret it, focus on the entire problem of technology and how do you use it, the supportive mechanisms that can be used by Government, and elimination of Government restraints.

Senator KASSEBAUM. Professor Suh?

Mr. SUH. Senator, I think the issue you are raising is very complex, and I think we have to be modest in setting up the goals for cooperative research to promote innovation, because there are many different forces acting on the innovation process. So I would like to touch on three unrelated topics which have some bearing on this whole issue.

We often use the word innovation in a very loose way. We have to talk about what kind of innovation we really need and what kind of innovation we would like to promote.

I think almost anybody can be innovative. A man who has no education can be innovative. The kind of innovation he may come up with may differ from the kind of innovation, say, IBM may come up with. So there are different degrees of innovation. Certainly as a society we cannot really downgrade the need to innovate regardless of the nature of innovation.

One of the things I think we're talking about in relation to this bill is innovations in the area of very high technology which requires some basic understanding of science. Such innovations will enable us to do the kind of things that no one else can do and

continuously push the frontiers of knowledge in such a manner that we can, indeed, afford the high standard of living we are enjoying today. Because we believe that cooperative research with industry is beneficial to MIT, we have started two more cooperative research programs at MIT with internal funds. With limited resources, the laboratory for manufacturing and productivity at MIT have started new cooperative research programs because we thought we could fulfill MIT's missions through them. We felt that we can somehow gather enough momentum and receive industry and Government support to provide us with the kind of funding needed to establish self-sustaining cooperative research programs.

One of the cooperative research programs is called MIT—industry flexible materials processing program that deals with generic issues involved in all sorts of flexible materials—paper, textiles, apparel, leather, footwear, what have you. We believe we can deal with the generic problems that are common in these industries. We are starting another cooperative research program called machine dynamics program.

We feel that we can inject new kinds of thinking processes in these two traditional areas and then provide higher order—I underline the words "higher order"—innovations.

We are committed to cooperative research because cooperative research is possible and benefits MIT as well as participating industrial firms. If we simply establish cooperative research centers, without looking at the long-range benefits to participating institutions—academia, industry, or non-profit research institutions—then I think it's not going to work.

In many cases I think that people jump into an area because there's a fund available. I think we have to examine our posture as to what kind of things will eventually lead to success. Success, meaning each institution achieving its goals and not simply just providing innovations. Educational institutions have to educate the students better, and have to promote research goals more effectively through cooperative research, while industry, by participation in such an effort, can make technological progress which cannot be made by the themselves or at a great cost.

And that's very important. The reason industry cannot do such things as we can do at MIT is very simple. At MIT, we represent a large number of scientific disciplines. We have 1,030 faculty members. When I say "faculty members," these are the people that rank from assistant professors up. We have 1,030. We have 25 academic departments. We spend $340 million a year; maybe $200 million on research. Therefore, we can think about things that small companies or even large companies, which are bound within a certain circular path in terms of thought processes because they have not been in that business for too long.

You might be interested in learning is that people who are working in the polymer processing program are not all polymer specialists. That's the unique thing about our program. That is, you would expect most of the professors involved would be the ones who received a doctorates in polymer processing or polymer science. That is not true. In fact, we have two professors in electrical engineering who haven't done much with polymers prior to their involvement in the program. We had a professor who worked in

the area of heat transfer. What we are providing for industry is new insight into a problem they have been looking at from one side. Even when we drive down the same familiar street many times we sometimes notice that, depending on from which end you drive down the street, it looks like a different street. I think many of the innovation processes occur because people have that new insight of being able to look at it from a different point of view.

The reason we are emphasizing at MIT this matter of institutional realinement is not to simply to promote innovation. We think we have something that no other institutions have because of the diversity of backgrounds and the diversity of expertise that we have available at MIT. We also know that external inputs are necessary for MIT. The academicians' normal way of doing research often goes through a circular path. That is, once we are a specialist in a given area for 10 or 20 years, we tend to approach our research in the same way most of the time. In order to break away from the circular thought process, we need to have outside forces challenging our way of thinking. At MIT we are bringing in industrial people to kick us out of our circular path, and we are helping industrial people to kick themselves out of their circular paths.

These are the reasons new institutional relationships make sense. That's the reason why I would like to see us work together with people in industry. I would like to see this whole process of institutional interactions bring such that somehow new elements to each institution that they themselves cannot secure on their own. That, I think, is what the issue is.

Obviously this kind of discussion takes a long time to highlight the pros and cons of a difficult subject, and I really don't know how to respond to your question in a very short, concise way. I feel that what we have to do—what the Government ought to do—is to provide a framework in which that kind of innovation process, namely different institutions synergistically interacting, to provide the kind of input they themselves cannot acquire. That should be the major goal of this bill.

In this sense, I do not think it is going to be done by an extensive study of statistics of how the Germans are doing, how the Japanese are doing. In a sense, I feel that's irrelevant. I think we have to find our own institutional relationships that are going to work in our country in maximizing the return on our R. & D. investment within the given societal constraints. Even IBM which has very good expertise in certain areas, may benefit by working with other institutions which have capabilities in certain other areas. For example, MIT's biochemists may shed a great deal of light on future computers.

An academic institution with a diverse background and expertise can help, I think, even IBM.

Dr. UDELL. Senator, in answer to your question, if you're talking about key incentives, I don't think there are any that are key, because we are dealing with an interdisciplinary process. It's multistage, and consequently there have to be technical incentives, commercial incentives, financial incentives. But I think that if you approach the question from a different perspective, there is a key, and that's merely the attitude in which we approach this.

One of the advantages—one of the real pleasures that I had in working with the National Science Foundation is that it's been an innovative environment. It's been an encouraging and stimulating environment in which to work. They have given us the freedom to fail and try new approaches, to try new techniques and see what would happen. And in some cases we failed. In other cases, I think we have been successful. The atmosphere has been one of encouragement for new ideas.

I think we have problems. I think one of the real problems of innovation in this country is attitude. Business World may have summarized it a year ago in a July 3 issue in an article on innovation when they said that one of the problems of innovation was a supercautious attitude of management. I'd like to extend that to the supercautious attitude of the universities as well.

We tend to focus more on success and downplay failure, and as I said earlier, one of the real advantages for us has been we have had a flexible environment in which we have tried new things. We have learned a great deal from our failures. I think as much from our failures as from our successes.

So again attitude is perhaps the key to which we approach this. We need to provide an encouraging, a stimulating environment for the centers.

Mr. BAUMANN. I think most of the university innovative environments that we have been talking about have been distorted. Something which I think is a very important thread that goes through several questions that Senator Stevenson asked and that you asked should be addressed.

Having grown up in the plains of the Dakotas and now residing in western Pennsylvania, I am very sensitive to the idea that whoever digs up the coal has to restore the environment. I think that the Government, in behalf of society's needs during the aerospace era has had a large effect on changing our engineering colleges to pure science. The proper role of Government, if it wants to use our innovation factories—engineering schools—effectively is to put them back to their original state. My testimony shows, I believe, that the engineering college was an American invention to replicate the Henry Ford's, Tom Edison's, Alexander Graham Bell's, who were the innovators and national heroes of their time. I'm afraid the universities didn't do a very good job. But as we went through this aerospace era, the role that seemed important to us on the faculty was to do things that implied that we didn't want to think about whether anybody would ever use our results. Many professors were hoping that some day their scientific endeavors would be recognized, and in three or four generations, people would read their collective works—basic research.

That science role model was so predominant in the aerospace era that I think it changed the educational approach of our major universities. And now we have the problem, and that problem is that too many professors cannot relate to industry, and most of us don't speak their language.

Senator KASSEBAUM. Thank you very much.

Senator STEVENSON. Thank you. You have been very helpful. The committee is adjourned.

[Whereupon, at 12:30 p.m., the committee was adjourned.]

# NATIONAL TECHNOLOGY INNOVATION ACT

WEDNESDAY, NOVEMBER 21, 1979

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
*Washington, D.C.*

The subcommittee met at 9:32 a.m., in room 6226, Dirksen Senate Office Building, Hon. Adlai E. Stevenson (chairman of the subcommittee) presiding.

## OPENING STATEMENT BY SENATOR STEVENSON

Senator STEVENSON. The subcommittee will come to order. Today we continue hearings on S. 1250, the National Technology Innovation Act. The bill is intended to improve the ability of universities and industry to cooperate through centers for industrial technology, in order to produce new products for the market. The bill also would improve the Government's ability to assess the technological and economic conditions that determine productivity, employment, and trade performances in specific industrial sectors.

The administration has been working on similar proposals. The President proposed four generic technology centers at a cost in fiscal year 1981 of $6 to $8 million. The administration also proposes to clarify the antitrust implications of cooperative R. & D efforts.

We look forward this morning to hearing more about the President's proposals, and with some hope of working with the administration to further our mutual purposes.

Our witnesses are Dr. Jordan Baruch, Assistant Secretary for Science and Technology of the Department of Commerce, and Ky P. Ewing, Jr., the Deputy Assistant Attorney General of the Antitrust Division of the Department of Justice. I will invite both these gentlemen to come up and join us. We will hear the statements of both witnesses and then proceed to some questions for both of them.

If you would like to summarize your statements, the full statements will entered in the record.

Dr. Baruch.

## STATEMENTS OF DR. JORDAN J. BARUCH, ASSISTANT SECRETARY FOR SCIENCE AND TECHNOLOGY, DEPARTMENT OF COMMERCE; AND KY P. EWING, JR., DEPUTY ASSISTANT ATTORNEY GENERAL, ANTITRUST DIVISION, DEPARTMENT OF JUSTICE

Dr. BARUCH. Thank you, Mr. Chairman.

It's a pleasure as always to appear before you to testify about industrial innovation, which is rapidly getting to be one of my favorite subjects. As you mentioned, in October, the President sent a message to Congress as a result of the domestic policy review on industry innovation. The President's announcement, which is a first step in forging a Government-industry relationship, is really a joint responsibility of the President and the Congress. The Office of Science and Technology of the Department of Commerce, of which I am the head, will be especially concerned with the monitoring of this relationship, as time goes by.

Mr. Chairman, I want to take perhaps the presumptuous opportunity of applauding you and your colleagues for initiating through S. 1250 congressional consideration of these extremely important areas of Government, to promote the technological welfare of U.S. industry. We in the administration are committed to working with you during the next session to refine, build upon S. 1250, in order to develop a piece of legislation compatible with the principles set forth by the President in his message to the Congress.

As you recall, Mr. Chairman, the President dealt with nine areas in his message: Enhancing information transfer; generic technology development; patent system; clarification of antitrust policy, which I presume the Assistant Attorney General will refer to in his testimony; fostering the development of small innovative firms; making Federal procurement more an agent of innovation; improvements to our regulatory system; a labor-management area, and finally, maintaining an ongoing supportive Federal climate for industrial innovation.

Because this subcommittee has been particularly interested in the generic technological area, I believe it would be useful to mention some points. In order for cooperative programs to work, we can learn a great deal from activities that have taken place in other countries. In those countries, some have been effective, some have been ineffective, and we think we now know why.

Clearly, we are not going to formulate a cooperative technology program on a different society which has different ethnic structures and different traditions. It's going to have to fit particularly our own free enterprise system and our culture.

A critical element in any such center will be careful analysis and planning at the industry and technology level to make sure the work is relevant. We want to make sure that the activities in generic technology development gives special attention to the needs and capabilities of small- and medium-size entrepreneurial firms, because of their centrality to much of what goes on in the innovation process.

And last, to secure the maximum ratio of public benefits to public expense, we look at the development of technologies that underpin industries or preferably, whole industrial sectors. President Carter announced his decision to establish four such centers. They will be established in fiscal year 1981 at the Department of Commerce, one will be established under the supervision of the National Science Foundation. They will be supported jointly by industry and the Federal Government with funding brought to 20 percent, hopefully, in the fifth year.

We recognize that four centers is a clear message that this is an exploratory effort on the part of the U.S. Government to initiate Government-industry cooperation to promote industrial innovation in the private sector.

The size of the program in future years will and should depend on the extent of the proposals we receive during the first year and during fiscal year 1980, and on the experience that we gain from our initial effort. The centers President Carter announced are quite analogous to those called for in S. 1250. Industrial, academic, and Government researchers will carry out a research agenda that is defined primarily by industry, and we are looking for the development of self-sustaining industry-supported institutions built on universities, existing nonprofit organizations, or any freestanding organizations.

We think it's important to mention that we don't want to burden those centers with additional responsibilities such as facilitating Government—industry-university transfer of information or education. We believe the primary task they have is sufficiently critical and sufficiently difficult that they must focus on it with a high degree of monomania.

We think that we would like to work with you to insure that any legislation offers a relatively high degree of legislative flexibility, so that as we learn from the operation of these centers, from the kinds of proposals we get from other input, we can make any changes that are indicated.

In summary, Mr. Chairman, we see an opportunity for the administration and the Congress to work closely together in the next session to develop legislatiom which will build on the substance of the President's program and build on the substance of S. 1250.

The administration is committed to working with you on this matter of great national importance, and I would like to add my personal committment to that.

I would be pleased to answer any questions that you may have.

[The statement follows:]

STATEMENT OF JORDAN J. BARUCH, ASSISTANT SECRETARY FOR SCIENCE AND TECHNOLOGY, U.S. DEPARTMENT OF COMMERCE

Mr. Chairman and members of the Subcommittee, it is always a pleasure to appear before you to discuss the topic of industrial innovation. As you know, President Carter, as a result of a Domestic Policy Review of Federal policies and programs that impact upon industrial innovation, announced in an October 31, 1979 message to the Congress, a wide ranging Federal program designed to stimulate and facilitate the advancement of industrial innovation in the United States.

The President's program utilizes many of the tools and mechanisms available to the Federal Government to promote the growth of domestic industry. The President's initiatives constitute a beginning in what must be a continuing effort to enhance the productivity of the industrial sector. This end will be accomplished through cooperative actions on the part of both government and industry.

The President's announcement initiates federal efforts to forge a better partnership between industry, government, labor and the general public essential to the advancement of industrial innovation. As we commence this effort, we fully realize that the primary responsibility for innovation in our economy resides with the private sector.

The Office of Science and Technology of the Department of Commerce, of which I am the head, will be especially concerned with monitoring this relationship.

Some of the programs announced by the President are the subject of S. 1250. It is deeply satisfying that the objectives of these programs are parallel to the objectives of the Subcommittee's bill.

I applaud you, Mr. Chairman, and your colleagues for initiating, through S. 1250, Congressional consideration of these extremely important areas of government action to promote the technological welfare of United States industry. The Administration stands committed to work with Congress during the next session to refine and build upon S. 1250 in order to develop a piece of legislation compatible with the principles set forth by the President in his message to the Congress.

As you recall, the President in his message specified nine areas where changes in Federal policies would be made to provide a better climate for industrial innovation.

Enhancing the transfer of information through greater efficiency in the National Technical Information Service, the establishment of a Center for the Utilization of Federal Technology, and increased dissemination of technical information developed abroad.

Increasing technical knowledge through the development of generic technology research and development and expanded joint university/industry research programs.

Strengthening the patent system by modernizing the Patent and Trademark Office and developing a uniform Federal patent policy.

Clarifying anti-trust policy.

Fostering the development of small innovative firms through expansion of the programs of the National Science Foundation and enhancing the availability of venture capital to facilitate the start-up of high technology based firms.

Opening Federal procurement to innovations by removing barriers now inhibiting the Federal Government from purchasing innovative products. Through its purchases, the Federal Government can influence the rate at which innovative products enter the market.

Improving our regulatory system.

Facilitating labor and management adjustment to technical change by developing forecasting capabilities that provide advance warning of industrial change and permit timely adjustments.

Finally, maintaining a supportive Federal climate for industrial innovation.

As the Subcommittee continues to consider legislation in the area of industrial innovation, we hope you will carefully examine the broad range of initiatives announced by the President.

It is our joint responsibility to provde the private sector with a clear understanding of the Federal Government's attitudes and policies so that the private sector can be in a better position to make decisions with respect to developing and marketing new innovative products and processes.

Since this Subcommittee has been particularly interested in generic technology, I believe it would be useful to discuss what the Administration found in or concluded as a result of the study of cooperative technology performed in response to an October 1978 mandate of Congress.

Cooperative programs to stimulate innovation are extensive in other countries but not all have been effective.

To be effective, any United States program would have to be designed to suit our free enterprise system and culture and repond to many forces in Americn society, rather than only providing a vehicle for research and development.

The key to identifying opportunities and organizing cooperative responses to generate productivity and trade enhancements is careful analysis and planning at the industry and technology level.

Any United States program to stimulate innovation should give special attention to the needs and capabilities of the small and medium-sized entrepreneurial firms which have been and are so central to the American process of innovation.

Any United States program should concentrate on development of technologies that underpin industry or industrial sectors. Because the benefit from advances in generic technology to any one firm (or even or one industrial sector) may be small, there is less investment in the development of such technologies than may be optimal.

In his message to Congress President Carter announced his decision to establish four non-profit generic technology centers at universities, at other types of existing non-profit institutions or as independent centers. Each will have a narrow mandate: to promote the development of commercially significant generic technologies fundamental to the advancement of technologies which cut across a wide range of industries.

We envision each center being established with funding from both government and industry, but assume that the Government's contribution will drop to 20 percent of a center's total funding in the fifth year of its operation. This effort will be initiated in 1981 with the establishment of three centers by the Department of

Commerce and one by the National Science Foundation. Each center will be targeted on a technology that cross-cut the processes of several industries, and has the potential for significantly upgrading industry. Each center will be disigned to complement and support, but not substitute for, efforts in the private sector. The estalishment of only four centers reflects that this is an exploratory effort on the part of the United States Government to initiate government/industry cooperation to promote industrial innovation in the private sector. It also takes into account the budgetary impact of other decisions related to industrial innovation which have been made by the President. As actual operating experience with the centers is obtained, the structure of the generic technology program may need to be changed. In future years the size of the program will depend on the proposals received and the experience gained from the initial effort.

In sum, the centers to be established in accordance with President Carter's announcement are analogous to those called for in S. 1250. Consistent with S. 1250 is the President's determination that industrial, academic, and government researchers will carry out an industry defined research agenda to develop generic technologies, and to do so at self-sustaining industry supported institutions. There are, however, some important differences. For example, we have defined a narrow mission for each center believing that incorporating more general educational functions or a general mandate to promote industry-university information exchanges could detract from the ability of each center to address what we believe should be its fundamental purpose: the development and transfer of generic technologies. The need to address these other concerns is however recognized and in fact reflected in other aspects of the President's program.

A high degree of legislative flexibility must be maintained if we are to be able to make the changes indicated as we gain experience not only with respect to our cooperative technology efforts but our whole spectrum of industrial innovation activities. The Administration and the Congress must closely work together in the next session to develop legislation which builds on the substance of the President's program, the substance of S. 1250, and what we learn as time goes on. The Administration is committed to working with you on this matter of great national importance.

I would be pleased to answer any questions that you may have.

Senator STEVENSON. Thank you, sir.

I think if you have time, we will proceed with Mr. Ewing, then come back to both of you with questions.

Mr. Ewing.

Mr. EWING. Thank you, Senator Stevenson, I am very pleased to appear today before the subcommittee to present the views of the Department of Justice on S. 1250.

As you know, this administration is strongly committed to the enhancement of industrial innovation in our society. With your permission, sir, I would like to ask that my full text, prepared statement, be inserted in the record and I will attempt now to summarize it.

Senator STEVENSON. Thank you, the full statements will be entered in the record.

Mr. EWING. I would like to begin by recalling President Carter's words in his message to the Congress on October 31. He said:

Industrial innovation—the development and commercialization of new products and processes—is an essential element of a strong and growing American economy. It helps insure economic vitality, improved productivity, international competitiveness, job creation, and an improved quality of life for every American. Further, industrial innovation is necessary if we are to solve some of the Nation's most pressing problems * * *.

The President, I think, benefiting from the domestic policy review that he began in April of 1978, recognized in his message the fact that many of the world's leading industrial countries are now attempting to develop a competitive advantage through the

use of industrial innovation and that we need to respond adequately to this challenge.

It's also important for us to realize that in taking the initiatives to enhance innovation, the President also recognized that our Nation's history is filled with rich tradition of industrial innovation and that we are still the world's leader in developing new products, new processes and new technologies.

We have done this and we will continue to do this with an economic system organized on the basis of free and competitive enterprise.

As you know, Senator, the antitrust laws have been described by the Supreme Court as the Magna Carta of our economic liberties. They are, of course, designed to enhance competition and free the competitive process of artificial restraints.

President Carter did note that by spurring competition, antitrust policies can provide a stimulant to the development of innovations. We are pleased to note, Mr. Chairman, that S. 1250 seems to recognize the continued applicability of the antitrust laws to the operation of centers for industrial technology.

I would like if I may this morning to discuss first the relationship between innovation and the competitive process, which is the basic organizing principle of our economy, and then turn to some specific comments on S. 1250.

We believe that particularly relevant to your consideration of S. 1250 is appreciation of the fact that innovation is as vital an element to the competitive process as the competitive process is to the success of this Nation's economy.

Having said that, I must also quickly say that having competition as the organizing principle of our economy does not mean that all joint activity is prohibited. To the contrary.

The antitrust laws clearly recognize that some joint activity may, in fact, be helpful to the competitive process. Antitrust analysis, therefore, is one of the best ways we have of distinguishing between those joint activities that will spur innovation and competition, and those that will harm innovation.

If a joint activity will have a positive effect on the overall rate of technological development, it's likely to be legal under the antitrust laws.

If, on the other hand, joint activity will impede or otherwise obstruct innovation, the antitrust laws are likely to prohibit. President Carter recognized in his message that innovation is a subtle and intricate process covering that range of events from the inspiration of the inventer to the marketing strategy of the eventual producer.

What may be useful at one end of the innovation spectrum may, in fact, be counterproductive at the other end of that spectrum. In general, I think we recognize that independent activities often maximize the rate of innovation.

In a competitive environment, businessmen have strong incentives to improve their products, to use research and development to get an edge on a competitor. Thus, the very fact of competition spurs the innovative process.

On the other hand, independent research activity does not always result in the highest feasible rate of innovation. Sometimes

the alternative to joint innovation is less or slower innovation, or no innovation at all. When that occurs, it's very clear that the antitrust laws recognize the need for appropriately structured cooperative programs.

To use the most obvious example, if an individual firm cannot do the research itself, the antitrust laws will permit that firm to join with another to do the research that otherwise would not be accomplished.

The basic issue in antitrust analysis of any proposed joint research project is whether the particular project will produce more innovation, or less.

My prepared text, Mr. Chairman, goes into some detail as to the factors relevant to the so-called rule-of-reason analysis under antitrust law of particular joint ventures.

In general, to assess the legality of a joint venture in research, it's necessary to consider the characteristics of the industry, the characteristics of the joint venture, and the characteristics of the proposed research.

If the cost and risk of the research in relation to its potential rewards are so great that no one would participate, no one would have undertaken it individually, then in most cases, they may do so jointly.

A project which is narrow in scope and short in duration would be less likely to have substantial anticompetitive consequences than a broader, lengthier project.

Joint research ventures among firms in noncompeting industries clearly create less antitrust concern than similar ventures among direct competitors. Likewise, joint venture among smaller firms in an industry would normally be less likely to have anticompetitive effects than a joint project among the larger and dominant firms.

Industrywide ventures that include all or most of the firms in the industry are most likely to have anticompetitive effects and, I might add, anti-innovative effects as well, reducing innovation to the least common denominator.

I think we have to recognize that joint research ventures in highly concentrated industries may be more suspect than those in less-concentrated industries, because the risk of parallelism is very high.

Another aspect that we always have to consider is whether there is access by nonparticipants to the benefits of the joint ventures work.

Finally, we must pay attention to any collateral anticompetitive restraints or activities undertaken in connection with a joint program.

For example, if the joint program prohibits the individual participants from otherwise engaging in independent research, it may well be a violation of the antitrust laws.

It clearly would be a disincentive to innovation. I have tried here to summarize what my prepared text discusses in greater detail about the kind of factors that go into an antitrust analysis.

I would like you to know that the Antitrust Division will shortly be publishing an antitrust guide to research joint ventures. We hope that it is directly responsive to the President's request that we clarify the antitrust laws.

We are trying to write it in plain English that can be understood well by businessmen and lawyers alike, and give some practical guidance by using examples from the business reviews that over the last decade we have, in fact, given, affirming the fact that industry may engage in joint research activities in compliance with the antitrust laws.

I hope that this brief discussion, Mr. Chairman, has at least set the stage for a realization that the antitrust laws are not only completely consistent with the national objective of technological development and leadership to which the President and this administration is firmly committed, but also to an appreciation that the application of antitrust principles to propose joint activities is, in fact, essential to the achievement of the critical goal of maximizing innovation in our society.

It's from those perspectives that the Department of Justice views S. 1250. Most important provisions of S. 1250 from our perspective are sections 6 and 7 which involve the establishment and operation of the centers for industrial technology (CIT).

I cannot, today, predict what kinds of proposals for CIT's would be submitted if S. 1250 were enacted. What concerns the Department of Justice is that some proposals for CIT's may be submitted, for example, by a group of leading firms in a market, and through that mechanism, they might be enabled to coordinate their basic and applied research programs and to eliminate effective incentives for technological progress.

I suspect that the subcommittee would be similarly concerned about any such application. For in those circumstances, not only joint activity but Federal funding may be unnecessary and unwise.

I hope the point illustrates and emphasizes what I believe to be the fundamental consistency between the antitrust laws and the objectives of S. 1250, namely, to expedite the rate of technological innovation in the United States.

We are pleased, Mr. Chairman, that in section 6(a)(2), the importance of individual competitive research is, in fact, recognized. Section 6(a)(2) refers to, quote, in which individual firms have little incentive to invest, the first principle I mentioned in discussing antitrust analysis. Safeguarding this kind of focus in our CIT's is appropriate and necessary, we believe, from my point of view. If joint activity and Government subsidy are not necessary for an effective attack on the technological problems facing an industry, then approval of a CIT in that industry would be inappropriate from the perspective of both S. 1250 and the antitrust laws.

And in industries where joint activity and Government subsidy are needed, a CIT with a larger size or scope, or longer duration than is shown to be necessary would similarly undermine the policies of both S. 1250 and the antitrust laws.

Conversely, if the inability of individual firms to enhance research makes joint activity and Federal funding necessary, the antitrust laws simply do not present an obstacle to the kind of appropriately structured project that S. 1250 would want to encourage.

For these reasons, we believe that S. 1250 contemplates and the policies which underlie it actually demand that the antitrust laws apply to cooperative research ventures in the form of CIT's.

We, therefore, suggest that continued applicability of the antitrust laws should be made explicit in any legislation along these lines.

My prepared text goes on, Mr. Chairman, to discuss the patent provisions of S. 1250 which recognize that some kind of exclusive rights to an invention may be necessary to insure that a firm will make the often risky investment required to bring an invention into production and to develop a market for it.

Consequently, we think that the general outlines of S. 1250 are consistent with the President's recent decision on Government patent policy.

I won't repeat what my prepared text sets forth as to the President's position, it was given in the fact sheet and the President's message.

But I would emphasize as a bottom line on that subject that we believe the administration's bill would provide a uniformity throughout the Government which should apply to CIT's, and consequently, the administration's proposal on Government patent policy would make the patent provisions of S. 1250 unnecessary.

Mr. Chairman, I hope these Justice Department comments will facilitate your consideration of S. 1250, particularly with respect to its antitrust and patent policy implications.

We will be glad to work with the subcommittee to develop legislation compatible with the principles enunciated in the President's message.

May I, in closing, reemphasize the administration's commitment to achieving enhanced industrial innovation set forth in President Carter's message to the Congress and its recognition that continued application of our antitrust laws will maximize the innovative achievements of our economy.

Thank you, Mr. Chairman. I will be delighted to answer any questions.

[The statement follows:]

STATEMENT OF KY P. EWING, JR., DEPUTY ASSISTANT ATTORNEY GENERAL, ANTITRUST DIVISION, DEPARTMENT OF JUSTICE

Mr. Chairman and members of the subcommittee, I appreciate the opportunity to appear before you today to present the views of the Department of Justice on S. 1250, the "National Technology Innovation Act of 1979." By authorizing federal seed money for certain joint research and development programs in "Centers for Industrial Technology" run by private industry and universities in cooperation with the Department of Commerce, the bill seeks to accomplish its general purpose "to enhance technological innovation for the improvement of the economic, environmental and social well-being of the United States."

This Administration is strongly committed to the enhancement of industrial innovation in our society. President Carter declared in his message to the Congress on October 31st that:

"Industrial innovation—the development and commercialization of new products and processes—is an essential element of a strong and growing American economy. It helps insure economic vitality, improved productivity, international competitiveness, job creation, and an improved quality of life for every American. Further, industrial innovation is necessary if we are to solve some of the Nation's most pressing problems * * *."

Benefitting from the Domestic Policy Review of Industrial Innovation which he had begun in April of 1978, President Carter's message recognized the fact that many of the world's leading industrial countries are now attempting to develop a competitive advantage through the use of industrial innovation, and that we need to respond to this challenge by developing our own policies for fostering this Nation's competitive capability and entrepreneurial spirit in the decades ahead.

In taking initiatives to enhance innovation, the President also recognized that our Nation's history is filled with a rich tradition of industrial innovation and that we are still the world's leader in developing new products, new processes, and new technologies, and in achieving their wide dissemination and use. We have done this—and we will continue to do this—with an economic system organized on the basis of free and competitive enterprise.

Our antitrust laws, described by the Supreme Court as the "Magna Carta of our economic liberties," are, of course, designed to enhance competition and free competitive process of artificial restraints upon it. As President Carter noted, "By spurring competition, antitrust policies can provide a stimulant to the development of innovations."

The Justice Department is pleased to note that S. 1250 seems to recognize the continued applicability of the antitrust laws to the operation of "Centers for Industrial Technology." This morning I would first like to discuss the relationship between innovation and competition, the basic organizing principle of our economy, and then turn to comments on specific provisions of S. 1250.

Particularly relevant to your consideration of S. 1250 is appreciation of the fact that innovation is as vital an element to the competitive process as the competitive process is to the success of this Nation's economy. Having competition as the organizing principle of our economy does not mean that all joint activity is prohibited. To the contrary, the antitrust laws clearly recognize that some joint activity may be helpful to the competitive process. Antitrust analysis, therefore, is one of the best ways we have of distinguishing between those joint activities that will spur innovation and competition and those that will harm innovation and competition. If the joint activity will have a positive effect on the overall rate of technological development, it's likely to be legal under the antitrust laws. If, on the other hand, joint activity will impede or otherwise obstruct innovation, the antitrust laws are likely to phohibit it.

President Carter recognized in his message to the Congress that "Innovation is a subtle and intricate process, covering that range of events from the inspiration of the inventor to the marketing strategy of the eventual producer." What may be useful at one end of the innovation spectrum may be counter-productive at the other end.

Independent activities often maximize the rate of innovation. In a competitive environment, businessmen have strong incentives to improve their products and methods of production through investments in research and development activities. Companies use innovation to help meet the needs of their customers better or more cheaply then their competitors and thereby to increase their profits. But firms which fail to keep pace with their competitors' innovative improvements may find their competitiveness reduced—and justifiably so. If cooperation or joint activity is substituted for competition, the incentive of firms to make and commercialize innovations can be reduced or even eliminated because none of the cooperating firms stands to gain or lose a competitive advantage over the others as a result of innovation. The antitrust laws are designed to preserve the competitive stimulus to innovation.

The relationship between innovation and free and open competition is illustrated by some industries in which regulation has unnecessarily reduced the opportunities and incentives for innovation. One of the reasons why the Antitrust Division has championed deregulation of the airline and other industries is that, as the President recently indicated,[1] the pressure of renewed competition in deregulated industries can be expected to trigger innovative new ways to cut costs and improve service.

Of course, independent research activity does not always result in the highest feasible rate of innovation. Sometimes the alternative to joint innovation is less or slower innovation or even no innovation at all. When that is the case, the antitrust laws recognize the need for appropriately structured cooperative programs. If, for example, an individual firm cannot afford by itself to finance a research program on an efficient scale, competition would not be unreasonably restrained by a joint research effort with a similarly situated firm because neither firm may be willing or able to compete on an individual basis.

The basic issue in antitrust analysis of proposed joint research projects is therefore whether the particular project will produce more innovation or less.

Because of the need to distinguish between joint research activities with beneficial effects and those with harmful effects, the antitrust standards applicable to such projects are flexible enough to take into account the broad range of factors which determine their effect on competition and the rate of technological development.

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[1] *See* p. 10 of the fact sheet accompanying the President's October 31 message to Congress concerning industrial innovation initiatives.

The governing legal standard is either (a) the rule of reason, which examines all the surrounding circumstances in order to determine whether the agreement on balance fosters or inhibits competition through research, or (b) the test of Section 7 of the Clayton Act, which considers whether the joint activity may tend substantially to lessen competition through research and development efforts. The rule of per se illegality, which is applied to types of business conduct, such as price-fixing, that are so likely to be anticompetitive that they are conclusively presumed to be unreasonable, is generally not suitable to judge the legality of joint research projects.[2]

At this point, it may be useful for me to summarize some of the factors relevant in a rule of reason analysis of joint research activity which determine the effect of such activity on the rate of innovation. In general, to assess the legality of a joint venture in research, it is necessary to consider the characteristics of the industry, of the joint venture, and of the proposed research. A type of joint venture permissible in one industry may be illegal in another, and the legality of one type of joint venture in an industry does not necessarily mean that other types are permissible as well.

One important consideration in antitrust analysis of a joint research project is the ability of the participants to conduct similar research individually. If the cost and risk of the research in relation to its potential rewards are so great that none of the participants would have undertaken the project individually, then the venture is likely to have the effect of increasing rather than decreasing competition. This may happen, for example, if individual firms lack the resources to finance independent research projects on a reasonably efficient scale. If, on the other hand, one or more of the participants actually engages in research on an individual basis or has a real potential to do so within a reasonable period of time, the formation of a joint venture may slow the rate of technological progress in the industry.

The structuring of a joint venture can affect its impact on competition. A project which is narrow in scope and short in duration would be less likely to have substantial anticompetitive consequences than a broader, lengthier project. One way to structure competitive problems out of a proposed research project is to confine its scope to basic research as opposed to applied research or product design or development areas. In many cases, even large firms may be unable to invest in socially desirable basic research efforts on an independent basis, and some pooling may be necessary to adequately fund the basic research effort.

Another relevant factor involves the relationship between the participants in a joint research venture. Joint research ventures among firms in non-competing industries create less antitrust concern than similar ventures among direct competitors. A venture among the smaller firms in an industry would normally be less likely to have anticompetitive effects than a joint project among the larger, dominant firms. Where only a relatively small part of an industry is engaged in joint research, the competitive incentive to innovate exists to stimulate not only members of the joint venture but non-affiliated firms as well.

In contrast, industry-wide ventures that include all or most of the firms in the industry are more likely to have anticompetitive effects. A firm that knows its competitors are not pursuing independent research that may give them a competitive edge may relax its own efforts, acquiesce in a passive, unimaginative joint research program, and even resist or deter innovation by the joint program that would adversely affect its own operations. In short, it cannot be assumed that the bigger a venture is, the better it is. On the other hand, the size and market share of the participants are only two of the factors which determine the antitrust consequences of a joint venture. Depending on such factors as the nature of the research and the likelihood that it would be done otherwise, participation of larger companies in cooperative research ventures may sometimes be highly desirable.

In assessing the effects of a joint venture on competition, it is also necessary to consider the characteristics of the industry. For example, joint research ventures in highly concentrated industries may be more suspect than those in less concentrated industries because the risk of "parallel policies of mutual advantage, not competition," [3] is especially high in these circumstances.

Another aspect of joint research ventures which must be carefully scrutinized is access by non-participants to the benefits of the venture. It is well established that exclusion of actual and potential competitors from the opportunity to share the results of, as well as to participate in, a joint research project on a reasonable basis may be a ground for concluding that the joint project violates the antitrust laws.[4]

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[2] Of course, if a joint research project is simply a sham for some clearly and deliberately anticompetitive scheme, no extensive investigation is necessary to determine that such a project is illegal.

[3] *United States* v. *Aluminum Co. of America (Rome Cable)*, 377 U.S. 271, 280 (1964).

[4] *Associated Press* v. *United States*, 326 U.S. 1, 15 (1945).

Where access to a facility created by a combination among competitors becomes so necessary to effective competition in a particular market that exclusion from that facility places an enterprise at a significant competitive disadvantage, it may well be unlawful under the Sherman Act to continue the operation of the facility without providing access to all competitors who desire admission.[5] This does not, however, mean that competitors must be given a "free ride." Access may be conditioned on payment of a fair proportion of the expenses of the project.

Finally, attention must be paid to any collateral anticompetitive restraints or activities undertaken in connection with the joint program. A joint venture that is otherwise legal may nevertheless violate the antitrust laws if it imposes unreasonable competitive restrictions on the participants. For example, agreements by the participants not to pursue independent research and development in competition with the joint venture or certain restrictions imposed on the licensing of patents or know-how resulting from the venture may constitute unreasonable competitive restraints. Other types of activities by joint ventures, such as the sharing of confidential information about costs, prices, and similar matters, also could tend to reduce or eliminate competition among them.

This brief description of the relevant factors in a rule of reason analysis of joint research ventures obviously is not comprehensive or exhaustive, and other factors also determine how the formation of a joint research venture may affect the pace of industrial innovation. An Antitrust Division "Antitrust Guide to Research Joint Ventures" will be forthcoming very shortly. It will be directly responsive to President Carter's request that we clarify the application of antitrust laws to joint research ventures and will provide a much more detailed discussion of these factors which I have only touched on now. The guide will discuss in straightforward terms that businessmen as well as lawyers can understand what kinds of joint research activities do raise antitrust problems and what kinds do not. In addition, the Guide will discuss concrete examples of typical joint research activities to give a better idea of how antitrust concepts are applied in specific factual situations.

Also in compliance with the President's Innovation Message directive, the Justice Department is intensifying its efforts to discuss innovation and antitrust policy with industry. For example, we will be participating in the colloquium being sponsored by the National Academy of Engineering on December 8th on "Industrial Innovation and Public Policy Options." We will continue to work with the Commerce Department, other Executive Branch agencies, and the Federal Trade Commission to clarify the application of the antitrust laws in the area of research and development. We also will continue, through our business reviews, speeches and participation in government-industry programs, to help dispel the mistaken perception that antitrust policy inhibits innovation or prohibits all joint activity.

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My brief overview of antitrust analysis of joint research ventures will, I hope, at least demonstrate its reasonableness and common sense. When joint activity is reasonably necessary to the effective pursuit of new technologies, the antitrust laws permit it, and they give businessmen reasonable and ample flexibility in designing such ventures. The antitrust laws do not erect an insurmountable barrier to joint research activities. Not to recognize the practical obstacles that now confront many firms in conducting R&D would be simplistic and shortsighted, and the antitrust laws take a much broader and more comprehensive view which fully considers the costs and risks which businesses face in pursuing innovative research.

Of course, the antitrust laws also do not take the equally erroneous view that joint research is always better than individual research or that bigger joint research projects are always better than smaller ones. Joint research may be necessary for some firms in some industries, but independent R&D remains the most effective means to technological development and innovation for many firms in many industries.

For these reasons, we believe the antitrust laws are not only completely consistent with the national objective of technological development and leadership, to

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[5] *United States* v. *Terminal R.R. Ass'n of St. Louis*, 244 U.S. 383 (1912).

which the President committed himself and his Administration in his recent message to Congress, but also that application of their principles to proposed joint activities is essential to the achievement of this critical goal of maximizing innovation.

It is from these perspectives that the Department of Justice views S. 1250. The most important provisions of S. 1250 in this respect are Sections 6 and 7, which involve the establishment and operation of Centers for Industrial Technology (CITs). These CITs would be affiliated with universities or other nonprofit institutions, and among their purposes would be the enhancement of technological innovation through cooperation between industry and universities, the development of a basic and applied research base in which individual firms have little incentive to invest, and the conduct of research relevant to governmental health, safety, and environmental regulations which would minimize the costs of duplicative research. Each CIT could acquire title to any invention developed under its auspices that was supported by federal funds provided that it satisfied the requirements of Section 6(e), but if these conditions were not satisfied, the government would obtain title.

Under Section 7 of the bill, the Commerce Department could finance a limited portion of the total costs of CITs, although the bill requires CITs to be financially self-sustaining to the maximum extent feasible. The bill sets out various standards which the Department of Commerce would use to determine whether to fund a particular proposed CIT, and it also would give that Department the authority to impose any necessary or appropriate terms or conditions on the organization and operations of any CIT.

I cannot, of course, predict what kinds of proposals for CITs would be submitted if S. 1250 were enacted. What concerns the Department of Justice is that some proposals for CITs may be submitted, for example, by a group of leading firms in a market which could enable them to coordinate their basic and applied research programs and to eliminate effective incentives for technological progress.

I suspect that the subcommittee would be similarly concerned about such an application, for in those circumstances, not only joint activity but federal funding may be unnecessary and unwise. That point illustrates and emphasizes the fundamental consistency between the antitrust laws and the objective of S. 1250 to expedite the rate of technological innovation in the United States.

Indeed, S. 1250 recognizes the importance of individual, competitive research. For example, one of the objectives of CITs under Section 6(a)(2) is to develop a generic research base "in which individual firms have little incentive to invest." Implementation of that goal would minimize the extent to which cooperative R. & D. would displace R. & D. conducted by individual firms.

Safeguarding this kind of focus is appropriate and necessary from any point of view. If joint activity and government subsidy are not necessary for an effective attack on the technological problems facing an industry, approval of a CIT in that industry would be inappropriate from the perspective of both S. 1250 and the antitrust laws. And in industries where joint activity and government subsidy are needed, a CIT with a larger size or scope or longer duration than is shown to be necessary would similarly undermine the policies of both S. 1250 and the antitrust laws. Conversely, if the inability of individual firms to finance independent research makes joint activity and government funding necessary, the antitrust laws would present no obstacle to the kind of appropriately structured joint project that S. 1250 would want to encourage.

For these reasons, we believe that S. 1250 contemplates, and the policies which underlie it demand, that the antitrust laws would apply to cooperative research ventures in the form of CITs. Application of the antitrust laws would reinforce the provisions of the bill and insure that particular CITs would be organized and operated in a manner that would not interfere with the efforts and incentives of individual firms to pursue technological research. We therefore suggest that continued applicability of the antitrust laws should be made explicit in any legislation along these lines.

Because the patent provisions of S. 1250 recognize that some kind of exclusive rights to an invention may be necessary to ensure that a firm will make the often risky investment that is required to bring an invention into production and to develop a market for it, their general outlines are consistent with the President's recent decision on government patent policy. The President decided to seek legislation that would establish a uniform government patent policy that would provide contractors or inventors with certain exclusive rights in inventions resulting from federally supported research and development activities. Title to patents issuing on such patents would normally be retained by the government, but an exception would be made for small businesses and universities in recognition of their special

place in our society. Contractors other than small businesses and universities could obtain exclusive licenses in fields of use in which they agree to commercialize the invention unless the agency determines that such a license would be inconsistent with either the agency mission or the public interest. In either case, the government would retain march-in rights that could be exercised in the event the invention is not commercialized or where a situation inconsistent with the antitrust laws results. The Administration's legislative proposal will be sent to Congress shortly.

By giving all CIT's the option to acquire title (provided that they meet certain conditions), S. 1250 may not square with the Administration's proposal which generally permits only small businesses and universities to take title to patents on inventions resulting from federally funded projects. Moreover, the patent provisions of S. 1250, if enacted, would perpetuate the piecemeal and often conflicting statute-by-statute and program-by-program approach which the Administration bill would replace with a uniform and comprehensive policy. The Administration bill would provide how patent rights in any invention, including those made by a CIT, would be allocated, so enactment of the Administration proposal would make the patent provisions of S. 1250 unnecessary.

I hope that these Justice Department comments will facilitate the Subcommittee's consideration of S. 1250, particularly with respect to its antitrust and patent policy implications. Dr. Jordan Baruch, Assistant Secretary of Commerce for Science and Technology, is addressing the question of whether enactment of S. 1250 is needed either to authorize federal funding of research or to achieve organizational changes within the Department of Commerce. The Justice Department, of course, defers to him on these matters. We will be glad to work with the Subcommittee to develop legislation compatible with the principles enunciated in the President's message.

May I, in closing, re-emphasize the Administration's commitment to achieving enhanced industrial innovation through the nine areas of initiatives set forth in President Carter's message to the Congress, and its recognition that continued application of our antitrust laws will maximize the innovative achievements of our economy.

Senator STEVENSON. Thank you. I commend you both and the administration for instructive attention to industrial innovation, and I do share your hope that we can work together to further this purpose, including through enactment of S. 1250.

Let's start with antitrust. I sense that the obstacle to cooperative R. & D. and participation in the CIT's is uncertainty about the application of the antitrust laws. If explicitly or implicitly the antitrust laws are to apply, how will that uncertainty be dispelled? Will a handbook, the clarification of the kind suggested, be enough? Or is something more necessary?

Mr. EWING. I think that any uncertainties that may exist can be easily clarified by our four mechanisms. First, I think the companies involved will go to their own private counsel. That is the first line of antitrust information to a company.

Second, we do hope that our guide, new proposed guide, which should be out very shortly, will assist businessmen in immediately understanding the parameters of antitrust principles.

Third, we are committed, obviously, to working with the Department of Commerce as part of the executive branch in giving advice on the structuring of any particular center for industrial technology.

Finally, I would note that we have, I think, a very good record of responding to businessmen through our business review procedure. We have had a number of joint ventures in research presented to us over the course of time, and we have responded favorably in almost all instances.

An example I happen to have in front of me this morning, back in 1976, there was a proposal of the Metal Treating Institute to—Metal Treating Institute is a trade association for 198 commercial

heat treating processors. They proposed a joint research project to study the efficient use of energy in metal heat treating. It was a short-term project, and the division issued a favorable business review with the understanding that the project's scope would be limited to the development of basic industry knowledge and would not extend to the question of how that knowledge could be applied to particular manufacturers' processes among the trade association members.

Moreover, the project's results would be made available on a nondiscriminatory basis to all industry members, regardless of their membership in the institute, and on a cost-sharing basis.

That is an example of how a particular group came to us under the business review procedure and promptly got a response that enabled them to go forward with almost complete certainty.

Senator STEVENSON. Mr. Baruch.

Dr. BARUCH. If I may add to that, in the operation of a generic technology center, at least as perceived under the President's directive, there are two levels of antitrust problem. Ky, in his testimony, pointed out that the makeup of the participants in such a center is an important consideration, are they leading firms, disaggregated firms, and so on.

So there will be one kind of review that looks at the makeup of the center since the center itself is not a project. The center itself has a longer life. Then, as projects are initiated within the center, there will be a second kind of review that says, is that particular project appropriate under the antitrust laws?

Senator STEVENSON. Review by who?

Dr. BARUCH. By the executive branch, presumably the Justice Department and the Commerce Department. We will be reviewing it from different perspectives, both aimed at the question of increased innovation.

It is important to note that we have discussed both of these stages with the Justice Department, and I think we are in a high degree of agreement on the kind of reviews that are necessary.

Most of the things that are in violation of the antitrust principles and the antitrust laws turn out to be inhibitory to innovation in fact. So I have very little concern about our ability to tackle these two stages compatibly with the Justice Department.

Senator STEVENSON. Well, I can tell you that your lack of concern is not widely shared. Industry, and to some extent, the universities, do have a concern.

Dr. BARUCH. Yes, sir.

Senator STEVENSON. And what you have said to me may heighten it. As I understand it now, two levels of review are contemplated, both for the center, then for individual projects that are undertaken by the center. And those reviews, even when they result in a green light, still won't protect the participants from antitrust actions by the Federal Trade Commission or by private suits. They won't even offer an iron-clad protection against action by the Justice Department.

Offhand, I just think that would be a severe disincentive and one that is not accepted in other countries with whom we are now competing. If I am right, then in the name of competition, we will again end up preventing ourselves from competing.

The EEC, for example, in its treaty, recognizes in articles 85 and 86, basically, that cooperative R. & D. is not anticompetitive. It attaches a positive value to R. & D. generically making a more or less blanket exemption from antitrust liability for cooperative R. & D. efforts. That is an example of the kind of competition we are up against.

You mentioned the need to distinguish between products or industries. I can't offhand, Mr. Ewing, think of any industry or product that needs to be distinguished. There won't be anything this year produced by the United States except arms that are unique or of superior quality in the world. Hitachi will come on with a generation of computers that is more sophisticated than anything IBM is producing.

Why is there this need, unless it is contemplated that Hitachi, or foreign companies will be participants within these new U.S. cooperative R. & D. efforts?

Let me ask first, is that contemplated? What will be the attitude toward foreign participation in CIT's?

Dr. BARUCH. We have not yet formulated a policy that is workable on foreign competition. The principle on which we are working, of course, is to try to give as much advantage as is possible to the domestic corporations.

But, Mr. Chairman, if I may, I would like to respond to your initial concerns. I would like to point out the kind of R. & D. which, if we took under the blanket—we would destroy our competitive ability, as it may theirs.

We might, for example, do research in the microlithography. That would be the kind of generic technology, I think, that would enhance our competitive position greatly.

We might also get firms together to work on an optimum computer architecture. A few years ago, that optimum computer architecture was single, freestanding central processors, operations code of 256 words, and so on. If all our firms latched on to that because we were doing joint research and development, and that was clearly the easiest thing to get into, we would lose the fuel that has led to the Craig Computer, that has led to multiprocessor computing, that has led to other approaches will, in fact, most likely provide the comparative advantage to American industry.

So our task, and when we talk about limiting R. & D. under the antitrust laws, what we are trying to do is build distance between the actual design of products, processes and the design, the development of the technologies on which firms which do compete can build successful products.

Senator STEVENSON. Well, I certainly agree with what Mr. Ewing said about the need to prohibit any agreements that would prevent or discourage a firm from undertaking independent R. & D. There is no question about that. That, it seems to me, is a relative easy kind of offensive behavior to identify and handle.

But if such forms of behavior are not identified and clearly marked as wrong, that uncertainty is going to hover over these centers in everything they do.

And you just haven't satisfied me as to how you are going to eliminate it in such a way as to encourage active participation by universities and businesses in these centers.

Now, other countries do it, and the products of their coopeative effort on R. & D. can be pretty impressive. At least, we have all started out I think that a recognition of a capacity for industrial innovation is critical to our competitiveness in a highly competitive international marketplace. And we have started out with that recognition because our position in that marketplace is being eroded by the rapid progress that other countries are making, much of it through cooperative R. & D. efforts.

And without the kind of disabilities that I anticipate, from what you have said, in this most modest attempt to begin doing what they are doing.

How do you do it? Can the Justice Department provide letters of exemption as it does for oil companies in their foreign operations, or some such, so as to remove some of these uncertainties, or minimize them?

Mr. EWING. Mr. Chairman, let me add to this record what I know that you personally already know from other hearings in which you have asked me similar questions. We attempt in the Justice Department to make our enforcement intentions plain through such means as guides, through such means as working with other executive departments and, finally, through the means of our business review procedure.

While that is not an iron-clad guarantee that in the future some different action will not be taken, in fact, it gives business greater certainty because, over the last decade, no activity cleared under our business review procedure has been challenged by the Justice Department. And, to the best of our ability to find out, no activity cleared under our business review procedure has been challenged by private planning.

So, in the practical world, we think this gives companies and company managements considerable certainty as to the legality of their activities.

I would add one other thing. One of the reasons for this is that we attempt in our business review letters to set out why we think it is okay, which is itself a disincentive for anybody to come and challenge it later because, hopefully, we have been good at giving the reasons why this activity is consistent with the antitrust laws.

In the case of joint ventures, I hope we can make them clear when we clear them that one of the reasons we are saying OK is that it will enhance that needed innovation in our society.

So I think that the very fact that we have a business review procedure which has started, the fact that part of that procedure is to set out the reasoning behind that decision will in fact greatly assist in the future to give the kind of certainty that will make these programs workable.

Senator STEVENSON. Do you contemplate this for each project within a CIT?

Mr. EWING. We contemplated, as Dr. Baruch has indicated, first, at the time of setting up a center, and then as to the operations thereunder, because the center might be composed of a university and two or three companies, some of their activities might be clearly legal under the antitrust laws if on the research end of the spectrum.

If, however, that center 5 years down the road proceeds to start getting into research that could only be described as designed to give product differentiation effects as opposed to anything basic, then we would be much more concerned under the antitrust laws.

So we would have to look at both the creation of the center in terms of structural problems and its operation in terms of what it was actually getting into.

Senator STEVENSON. Let's also assume that the project is undertaken and that the review procedures have been satisfied. At that point you are not going to know what that project is going to produce, what the technologies are, or the marketability and utilization of the technologies.

Are further review procedures contemplated too, because down the road, if it is successful, you are going to have all sorts of possibilities in addition to the patent questions which you have already addressed, that involve the commercialization of the technology, and, I would think at that point, additional antitrust implications?

Dr. BARUCH. Mr. Chairman, this is an area that we have discussed extensively, both with the Justice Department and industry. Once the technology is developed, and we assume it is in truth generic technology, then it becomes up to the individual private firms to decide first whether they want to incorporate that generic technology into their products and, if they do, go ahead and do it.

At that point, however, they can no longer participate with the other members of the group in deciding who will, how they will split up the market. That one will take cassette recorders and one will take reel to reel recorders. That would be clearly anticompetitive and against the antitrust rules.

But if from the point of view of the development of the generic technology they purview their product developments independently, that would not have antitrust implications. That is what is done all the time now in industry.

Senator STEVENSON. But this gets back to a question I have already raised. If history is any guide, foreign firms may wind up utilizing and benefiting from the technologies produced before the American firms. How are we going to take care of that one?

Dr. BARUCH. Sir, if that is the case, then we have a problem with our private sector.

Senator STEVENSON. Well, we do.

Dr. BARUCH. It is not a problem that is a governmental problem. If private firms overseas, or overseas competitors can take a technology that has involved participation of actual people from American firms who are then to go back to the firm and incorporate their knowledge into product design, if they can take that information based simply on published literature or whatever else comes out, it would be an enormous, would raise enormous questions about whether there are other problems within our economic system than antitrust problems that cause our firms to be noncompetitive.

Senator STEVENSON. Well, those questions have been raised.

Dr. BARUCH. Yes; those questions are raised continuously. One of the myths prevalent in the United States is that there is some way of stemming the outward flow of technological information from

the United States to foreign countries. I call that a myth because there is no practical way of doing it unless we build walls around the Nation. If we want to prevent the flow, we are stymied.

It deals with our basic fundamental freedoms. We would have to stop the travel abroad of knowledgeable people. We would have to stop the availability of our publications abroad. We would have to resign from the world information—world intellectual property organization. Our defense against this, what I have called the leaky bucket phenomenon in other testimony before you, Mr. Chairman, is we have to keep that bucket filled more rapidly than the information leaks out.

Now, we still find that in most of our industries, foreign competitors adapt American-developed information slower and later than American firms do. There are many reasons for that, having to do with the networks that exist within our society. It used to be, however, that it took 10 years for a British company, for example, to capture the technology developed by an American chemical firm. It now takes about 3 years for them to capture that technology because they are getting smarter, they are getting better connected to our networks.

But there is no way that I know, except increasing the inherent vitality of our industry, to insure that we maintain that lead. I see no way of stemming the flow of information, nor do I see any indication that stemming that flow would be consistent with other values in our society.

Senator STEVENSON. No, I agree with that. But I do think more could be done to promote technology utilization in the United States.

Dr. BARUCH. No question.

Senator STEVENSON. We have, for example, in NASA a very modest technology utilization effort. It produces economic benefits many, many times its cost. But technology utilization is a haphazard, spotty, uncoordinated effort throughout the Government.

Now we are contemplating some new Government partially financed centers. So my question to you is not so much how you stem the tide of information. I think basically that is a two-way street and it ought to be facilitated. I don't mean to suggest we ought to punch holes in the bucket, but the flow of information both ways is healthy.

On the other hand, we could be doing more, could we not, through technology utilization efforts, to make sure that the benefits of Government-supported technology do get utilized in industry?

Dr. BARUCH. Absolutely, Senator. As a matter of fact, in the President's message you will note that he refers to a center for the utilization of Federal technology, which is an effort to extend the precepts of the NASA system where NASA is primarily familiar with those industries with which they have affiliation because of their mission, to getting the information out from Federal laboratories to a wide range of industries. It is a program that industry has been particularly interested in.

We see ourselves acting more as a nexus than as a marketing agent in that area. Getting together with groups from industries, finding out the needs and opportunities that exist, getting together

with the laboratories and getting into the laboratories to see what technologies might be applicable. This is an active transfer program.

Senator STEVENSON. It would apply to the centers, too?

Dr. BARUCH. Oh, yes. One of our strong hopes is that we will be able to integrate the planning function of a center. Remember, in my testimony, the President's message, one of the important underpinnings for the generic technology centers is their ability to do analysis and planning. Part of the data that will be used in that analysis and planning is what other research is going on in Federal laboratories so that we don't do duplicative research and so that we can use the same group to insure the transmission of information for both.

The centers, however, will have an additional group of their own. Each center will have associated with it a group that provides for firm specific consultation, which is an effort to provide direct transfer of technology, in addition to which we hope that the research at the centers will rely heavily on people sent by the individual firms to those centers, because the best way to transfer technology is in people's heads, not in documents.

We are very cognizant of this effort. If we were just to develop generic technology and wait for the Nation to beat a path to the center's door, it would be the kind of thing that is undertaken in some of our foreign countries where failure has been rife.

Senator STEVENSON. Why don't the innovation proposals include any organizational suggestions? As you well know, we are considering various proposals for reorganizing the Department of Commerce and to elevate and centralize authority for trade. I don't see any comparable effort on the technology innovation side.

Wouldn't it be wise, if there is to be, for example, an undersecretary of that department for trade, to have one for technology innovation? Try to elevate the responsibility for this subject to a level that is at least close to the level recognized in most countries?

Dr. BARUCH. It is clear the Department of Commerce does have multiple functions. We will have an under secretary of trade. We have the equivalent of an undersecretary of NOAA. I think in our statement that we look forward to working with you on building upon S. 1250, organizational questions are sure to come up. You have one already in S. 1250 where you have recommended a director of the office for technological development; I am sorry, I forget the exact name.

But I think the consideration of that organization ought to wait until we see what other items are brought into S. 1250 as a whole and what the responsibilities of the Department of Commerce are in this area.

Senator STEVENSON. Dr. Baruch, could we have a copy of the IRI survey done for the Commerce Department on industry attitudes toward generic technology centers?

Dr. BARUCH. We will be happy to provide that for the record.[1]

Senator STEVENSON. Thank you, sir. I understand from your statement you propose to add some aspects of the President's program to S. 1250. Could you tell us what should be added to S. 1250?

[1] See p. 356.

Dr. BARUCH. Well, I think if S. 1250 is a bill to enhance industrial innovation, and comes before the Commerce Committee, there are several areas in the President's fact sheet, in addition to general technology, that represent responsibilities under the Department of Commerce. Whether those should be embodied in legislation at this time I think will be a subject for discussion as we work with you.

But we can point to some of them that are quite obvious, center for utilization of Federal technology, which I mentioned before. Our whole effort in capturing foreign technology, it is no longer the case where the only technological gains that can be made by other countries are based on our research. Clearly that is a responsibility of the Department.

Senator STEVENSON. That proposal has drawn fire, some rather sarcastic comments about all the money proposed for the debriefing of tourists.

Dr. BARUCH. I think if the Commerce Department were to debrief the general tourists, we would need six more buildings the size of the one we have. That is not the intention.

The fact is that many foreign visitors who contact our science attaches and counselors abroad have a very good knowledge of the state of technology in the United States in a particular area. Are willing, as they go about providing information, say for the Japanese, of soliciting information from the Japanese.

It is all too often that our visitors go overseas, sit in a meeting with the Japanese and get milked dry with no quid for their quo. It is our intent of gathering information that would be useful to the United States and at least as important, providing a place where they can deposit that information, where that information can be aggregated, catalogued and disseminated to industry.

This is not a casual program of debriefing visitors. It is a program of interviewing technically competent people. We will also when we see a particularly interesting trajectory underway, be sending a group overseas, particularly targeted looking at that technology. These will be a group who will have the competence to provide information to foreigners about what we are doing as well.

Our task here is to make sure that what has been a one-way flow becomes a two-way flow. Whether it requires legislation or not, I think there are some advantages to having this in legislation when it is not required. It indicates, for example, a common commitment on the part of the Congress and the executive toward a goal. We have the corporations for innovation development, which is one of the President's moves, experimental program.

Clearly, I think, might well be considered as we build upon S. 1250. Lastly, of course, we have the whole question of the Presidential award for industrial innovation. It is symbolic. It is easy to laugh at. It has been laughed at by many who have also indicated that they intend to struggle very hard to win one. It is a recommendation that was supported very heavily by the IRI, the organization you mentioned earlier. That is an area that might take on an additional importance in the national view if it were both a congressional and an executive commitment.

So while I am—I am not a lawyer, so I can't address what requires legislation. I can see opportunities for us to work together to get a common purpose expressed through legislation.

Senator STEVENSON. S. 1250 calls for analytical and policy studies of key industrial sectors worldwide and technological developments that may become important to the American economy. This is section 5 of the bill. What is your reaction to that section?

Dr. BARUCH. Mr. Chairman, we are, just as you may know, restructuring the Bureau of Industrial Analysis of the Department of Commerce. That is an extention of the responsibilities of the chief economist. And it is our expectation that one of the extentions of that responsibility will be to conduct the kind of analyses that are supportive of determining what is the differential impact of new technologies in industrial sectors, so that we know where we are, where our basic opportunities lie and where we can get a marginal advantage.

Senator STEVENSON. Do you think that is responsive to the section 5 suggestion for sectoral studies and analyses?

Dr. BARUCH. They will be doing sectoral studies of the economics. We are working with them now so that they can factor into those studies a sectoral study of the level of technology of those industries as well. Even more important, the differential impact of changes of technology on the economics of the sector.

If that is not what you intended, I need to be corrected.

Senator STEVENSON. I think we are close enough so that we can work out what few differences there may be.

How would the research and development priorities of these centers be established? The projects, for example, how would they be identified?

Dr. BARUCH. The analysis of planning group within the center will be looking at those areas where we have the maximum potential for producing a competitive advantage for the entire industry. We will try to rank proposed projects based on their potential impact and, of course, on their cost. It will be done largely by industry, but with the close involvement of government participation, simply because we are concerned largely for the public benefits that arise out of such innovation.

Senator STEVENSON. You say the benefits for the entire industry. Then I guess the question is, how are the industries identified?

Dr. BARUCH. For example, if we were working in microlithography we find that industry has a wide range of projects in mind in the area of microlithography. Some involve getting to smaller and smaller lines. Others involve getting more complexity on a given chip. Others involve reducing the costs of the materials involved.

We would work with industry to decide which ones would have the greater impact on the competitive position of the entire industry. From where I sit at the moment, the increased complexity and the fineness of lines would be closely linked projects and would have a very considerable impact on the ability of our industry to produce more complex circuits at lower cost.

We would probably choose that as one of the first targets.

Senator STEVENSON. Have you considered the possibility of integrating these innovation efforts with the other responsibilities of

the Commerce Department—soon to be enlarged by law, for adjustment assistance including adjustment assistance through the Economic Development Administration—EDA?

Dr. BARUCH. EDA.

Senator STEVENSON. To companies and workers suffering from dislocation, and have the need for assistance. You know what's coming. We have a case in point, a big one. Your innovation proposals, already pointed out, included $55 million in new money. They were sent up here the day before the administration sent up a little $1.5 billion package for an industrial dinosaur called Chrysler.

There are some adjustment policies, transferring people and assets of that company to other enterprises, for the production of things for which there is a market. EDA has responsibility for rendering that kind of adjustment assistance right now. It is going to be enlarged substantially. If I have my way it will be enlarged more so that we can respond to situations such as this with support that is geared to the future instead of towards the subsidization of the geriatrics.

It occurs to me, and it really hadn't occurred to me before this, that those responsibilities are not unrelated and might be integrated in ways that could involve the production of technologies for the survivors of these industrial wrecks. Have you thought about that?

Dr. BARUCH. Yes, sir. You may remember in the dim past, our early thinking about cooperative technology, cooperative generic technology development focused one-sidedly on impacted industries. We have extended that because we know the advantage in our potentially lean industries.

We have not completely given up the other situation, however, where we are still working with various industries called geriatrics, in order to make them again competitive. The question you are asking is a much more—much further-reaching question.

That says, what happens when an industry goes out of business, like buggy whips? Do you spend Federal funds in more efficient production processes for producing buggy whips or fancier designs for buggy whips, or do you spend Federal resources and intellectual effort in finding gainful employment for the capital and labor forces represented by the buggy whips industry?

In the President's message one of the most undernoticed items was the labor technology forecasting system. When you talk about Chrysler, you are talking about a crisis that has already happened. To use newly developed technology to fight crises that have already happened is quixotic in the least.

It takes time for technologies to develop and to build industries around them. Nonetheless, we know enough about technological forecasting to look at many industries and see that new production processes, new consumer demands, customer demands, market structures, are going to require changes, changes which would cause dislocations in the labor force.

If we can find those things 4 years, 5 years in advance, and we think we can, then labor, management, and government can work together on just the kind of scenario that you are proposing. Namely, a scenario that says, how do we change our labor, how do we change the target markets of what we are doing, how do we

indeed change the productive activity of the production unit that we are considering?

We think those things are possible. They are not appropriate solutions to a crisis that has already taken place, however. My hope is that, if we do that job well, and pay sufficient attention to it with the help of the government and industry, that we will find fewer and fewer causes to have the kind of problem to which you are refering in the automotive industry.

Senator STEVENSON. We may have a few more questions in writing. I have got to get back to Chrysler.

I accept what you say. I don't take it as negative toward the kind of adjustment I want to provide in Chrysler. The proposition there is somewhat different.

It is a question of whether we are going to utilize these resources through a failing company, or through enterprises that are viable and hold out some hope for utilizing them productively and efficiently. By resources, I mean people as well as physical assets.

It happens the EDA has the mandate to do this, including training of people. We can go that way, into the future. We can go the other way, into the past.

We want to get this bill moving. I don't know of any opposition to it, though obviously there are points that need refinement. And it may need some additions.

But the support is broad; the opposition is thin. I think with some more cooperation we ought to be able to refine it quickly and get it passed quickly. I hope we can continue this effort and get more specific suggestions from the administration so we can get it reported maybe even this year, enacted by the Senate early next year, so we are sure it will become law next year.

Dr. BARUCH. Mr. Chairman, I assure you of our intense desire to cooperate in that effort. By "our," I mean not just my office but the Office of Science and Technology Policy and the remainder of the administration.

Mr. EWING. I will just add that the Justice Department will commit itself, has committed itself to working with your subcommittee on this, Mr. Chairman.

Senator STEVENSON. Thank you, sir. We will follow up. We are grateful to you both and look forward to working with you. Thank you.

The meeting is adjourned.

[Whereupon, at 10:44 a.m., the hearing was adjourned.]

## ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

CALIFORNIA INSTITUTE OF TECHNOLOGY,
*Pasadena, Calif., June 14, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space, Committee on Commerce, Science and Transportation, U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Thank you for sending me a copy of the bill S. 1250 that you have introduced into the Senate.

I believe that our government has shown too little concern with industrial productivity, either in measuring and studying our position in the world or in encouraging rather than discouraging productivity. Particularly, I have seen that in Japan the government and universities work together with the private sector in a way that is very effective—and that would be considered collusive here.

I think that the bill you sent me is a very good start. To benefit the country it must seem beneficial to universities and to private industry, and it is conceivable that there might be snags that I don't see.

I do urge you on in this good work. Thank you again.

Sincerely yours,

JOHN R. PIERCE,
*Professor of Engineering.*

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AMERICAN ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE,
*Washington, D.C., June 14, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology and Space,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: I have your memorandum of June 8, 1979 requesting comments on S. 1250, The National Technology Innovation Act of 1979.

Your introductory remarks in the Senate on May 24 provide a cogent and accurate persepective on the troubling trends in U.S. technological risk-taking and innovation. I am very glad to see your Subcommittee taking steps to focus attention on these problems.

S. 1250 represents, in my opinion, a limited but constructive move to link universities and industry in cooperative research and development. The bill is not excessively prescriptive, and affords wide flexibility for the parties to design and conduct policy experiments and to create an atmosphere of problem-solving. This is a good start on a complex set of problems. I am equally encouraged to see that S. 1250 would create a center in the Department of Commerce aimed at finding out some important things that we don't know about the interrelationships between innovation and productivity levels. I think it is high time that this kind of concentrated policy analysis gets focused in governemtn.

I wish you success with the bill.

Sincerely,

WILLIAM D. CAREY,
*Executive Officer.*

W. R. GRACE & CO.,
RESEARCH DIVISION,
*Columbia, Md., June 20, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, D.C.*

DEAR MR. STEVENSON: This is in response to your memorandum of June 8 soliciting comments on S. 1250, the National Technology Innovation Act of 1979. Basically the concept of creating Centers for Industrial Technology is a sound one. Much of the success of this concept, however, will depend on how well the act is administered. For this reason I have serious concern regarding those sections of the act which outline the duties of the Director of the Office of Industrial Technology. I fear that three years of bureaucratic paper shuffling and academic studies will tend to take precedence over bold forays into actual Research and Development. Section 5 of the bill is just the kind of activity bureaucracies love to get their hands on. It enables them to churn out paper after paper without ever taking a concrete act or taking a concrete initiative that requires bold decision making. In contrast, a bold Director already knowing what the problems are could lay out a comprehensive program in a matter of months.

I have long been an advocate of closer cooperation between industrial and academic laboratories. I have urged that the objectives of industry and academia could be mutually satisfied by the establishment of consortial relationships between them. By a combination of direct industry funding and royalties, I think it would be possible to reduce the annual struggle for program funding which university departments are now subjected to by the federal government. On the other hand, the act you propose is silent on the actual funding mechanisms contemplated. However, I can assure you that if the funding mechanisms contemplated are similar to those now in use by government agencies, we shall not have taken a significant step forward.

It would be far more productive to have the Centers propose continuing programs in certain agreed upon areas of concentration which would be continued for certain pre-stated periods of time provided certain programmatic objectives continue to be reached. I also think it would be productive to have these program areas approved by the Industrial Technology Review Panel but with strong industrial input. The major portion of the program of the Centers should be directed towards specific industries or groups of companies after reaching mutual agreement that these areas represent product and process targets that specific companies or industries would be interested in commercializing into businesses. Contrariwise, there is no point in having the Centers concentrate on areas where there is no industrial advocate committed to commercialization.

For a system of this type to work, some considerable input from the industrial sector would be required and in all likelihood some proprietary guidance would be needed. For this reason it is difficult for me to imagine that a company would risk its proprietary background patent property if not properly protected in advance. Similarly, the priority emphasis under Section 6(e)(3) on non-exclusive licenses, is discouraging. It is important for you to understand at the outset that industrial concerns do not take financial investment risks on a non-exclusive basis. The priority emphasis of your act should be on exclusive licenses with non-exclusive licenses possible as a secondary position where exclusivity is not required, not vice versa as the act now reads.

The act is silent on the licensing mechanisms to be used. I would prefer to have the act spell out that industrial concerns desiring licenses will deal directly with either the Director or the specific Center and that no third party brokers or intervenors will be permitted to take an additional slice of the royalty pie.

I am also concerned that the exclusive license will be limited to the "time necessary to allow for recoupment of investment by the licensee". What the government may consider recoupment of an investment may be entirely different from an industrialist's version of recoupment of an investment. For example, if a company puts a certain number of dollars at risk, it expects a multiple of those dollars back in return for a successful venture. Recoupment of the investment in industrial terms really means receiving a level of income commensurate with the financial risk rather than simple recovery of dollars invested.

I hope these comments are helpful and wish you well in your attempts to address an important national problem.

Sincerely,

LEONARD V. TRIGGIANI, *President.*

STATEMENT OF ERIC P. SCHELLIN ON BEHALF OF NATIONAL SMALL BUSINESS ASSOCIATION AND NATIONAL PATENT COUNCIL

Mr. chairman and members of the committee, my name is Eric Schellin. I am Chairman of the Board of Trustees of the National Small Business Association (NSB), a multi-industry trade association representing approximately 50,000 small business firms nationwide. I am also Executive Vice President of the National Patent Council.

We commend the committee for the opportunity to address the issue of diminishing invention and innovation in the United States, especially that activity that completes the innovation process by making available to all of us alike the benefits resulting from R. & D. endeavors.

That kind of legislation that is exemplified by S. 1250 is long overdue. Recent studies have shown that in a majority of highly industrialized countries there is a real partnership between the government and the private sector that provides the means for the government to continue to do the beneficial work that impinges on the quality of life. In other words these studies have shown that the government has assumed a participatory role as opposed to what may be termed an adversary role. These studies have shown that almost anything that we can think of that might be of assistance to business to increase innovation has in fact been utilized in order to enhance economic opportunities.

Therefore, we of the small business community applaud the endeavors represented by this proposed legislation.

It can be validly stated that the outstanding characteristic of our civilization is its complete dependence on invention and innovation. We are entirely surrounded by inventions and their resulting products. Our very existence, our comfort, and happiness are at the mercy of invention and innovation. Every fiber of our social system is permeated with invention. It is the keystone of our civilization and the very lifeblood of its existence. Take our inventions away and we would be plunged into barbarism overnight. Only a handful of humanity could possibly survive such a calamity.

Maurice Nelles, a former industrial research director, has stated:

"The historians of the future may well select the development of deliberate creativeness as the most important development of this country. We have passed through the age of random creativeness and are entering an age of deliberate creativeness. With this technique there is almost certainty that we can fulfill our needs, desires and whims in the future. The rate at which we can develop will be increased enormously and, if the same or analogous techniques are applied to other fields, man will not only be mindful of himself, but will understand himself and his interactions with his environments. What we have today is wonderful; but what there will be tomorrow will be much better."

We therefore submit that the analysis of the nature of relevant creativity should be one of the chief intellectual commitments of our age and armed with appropriate information to establish a policy that will further relevant creativity.

From the Congressional Record of May 24, 1979 it will be recalled that with the introduction of S. 1250 very valuable and elucidative remarks and comment were provided. Permit me to now repeat one sentence of those remarks, to wit: "Small, high technology companies have introduced a disproportionate share of new products and manufacturing techniques."

The quotation is quite accurate. It should be noted that the House Small Business Committee in its 1978 report on "Future of Small Business in America" stated that small business between 1969 and 1976, "accounted for what can be considered virtually all the new private sector employment in this country." Further, the companies in the "Fortune 1000" contributed less than 2 percent of the growth in new jobs. We refer you also to our report "Small Business Views With Regard to Invention and Innovation" appended to these prepared remarks. I would ask that this report be made a matter of record.

The aforementioned report is a result of the fact that we at NSB were deeply concerned that the majority representation on the private sector committees came from big business. Therefore, the views presented to the task force agencies did not fully represent the views of that sector of the economy that is most adept on invention and innovation. In essence, the report is designed to distill the small business point of view as exemplified in each of the private sector subcommittees. We have submitted this report to appropriate committees of the Congress, have submitted the report to the Assistant Secretary of Commerce of Science and Technology, and also directly to the President. We would like to point out that some of the things S. 1250 is to achieve is also the subject of some of our recommendations.

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As a first statement, we find it somewhat difficult to understand why small business has not been singled out for special attention in this proposed legislation. Perhaps there is a thought that there is no oversight as the functioning of the Centers for Industrial Technology will inherently involve interaction between universities and small business. However, it is well known that the university sector is quite comfortable working with big business. Some language clarification is in order.

Furthermore, the very nature of the bill in emphasizing universities and non-profit organizations makes it again seem to be axiomatic that business merely exists to provide jobs, to be taxed and to be regulated. Quite frankly, we find it difficult to recognize as the Bill does that business itself should play no part in the administration and the setting up of any of the centers.

A number of points should be remembered:

(1) Small business encounters problems that are frequently very different from those of big business.

(2) Universities and other non-profit organizations have rarely been more than a distant midwife in the setting up of new business ventures.

(3) Universities and non-profit organizations pride themselves on their integrity.

(4) Small business has limited independence as it must react to the buffeting of the market forces and government interference.

(5) Universities and other non-profit organizations frequently feel that they are prostituting themselves when working on applied research.

(6) Universities and non-profit organizations seek long term commitments while business looks for the immediate or short term commercialization.

(7) Finally, both big and small business pursues a profit motive while universities and non-profit organizations do not.

As a result of the foregoing it may be questionable without business' direct participation whether the university and industry can actually interact successfully together.

We have given careful consideration to the specifics of S. 1250. It is noted that the primary thrust is to legislate into existence an Office of Industrial Technology in the Department of Commerce. The Office will be headed by a Director who will have duties under section 5(c) to set into motion various studies.

Under section 6, the Director shall provide assistance for the establishment of Centers for Industrial Technology at universities or non-profit institutions. As stated before, we see no reason to exclude organizations that pursue the profit motive.

A third area should be added. The Director should be provided with sufficient funds to supply universities and non-profit organizations up to one-half of 1 percent of the value of a government contract, which funds must be set aside to establish viable technology transfer of the results of a government contract so that commercialization may be affected with small business being preferred as the recipient of the technology.

We feel that the wording employed to describe the "objectives" of the said Centers aid the "activities" of the Centers is not of the kind that makes for ready understanding to our constituency which should be that group that must be reached by these Centers. Permit us then to share with this Subcommittee if not more descriptive language at least more terse wording:

Objectives of the Centers:

1. Assist in commercialization.
2. Provide how-to-do information.
3. Research to more satisfactorily conform to regulations.
4. Create a climate to be creative.
5. Assist in use of Federal laboratories.
6. Obtain non-governmental funds to sustain the Centers.

Activities of the Centers:

1. Research leading to commercialization.
2. Assistance in evaluation.
3. Extension type services.
4. Curriculum for entrepreneurship.

In conclusion, we of small business support the primary thrust of the philosophic intent of the legislation but believe that if it is to go forward at all, the position of small business must be identified in the proposed legislation. We appreciate the ability afforded us to present this statement.

## Appendix

## Small Business Views With Regard to Invention and Innovation

### SUMMARY OF RECOMMENDATIONS

Declines in the growth rate in productivity have contributed to the present problems of the U.S. economy, and have given rise to the need for consideration of specific remedies. Such was the reasoning used in the creation of an Advisory Committee on Industrial Invention and Innovation appointed by Secretary of Commerce Jaunita Kreps, at the direction of President Carter, in the latter part of 1978.

In the spirit of suggesting practical remedies to the decline of American productivity, and the larger problems created by this reversal of a traditional American strength, the National Small Business Association and the National Patent Council have approached the considerations of the committee from a unique and different point of view—that of small business—than that taken by the Subcommittees formed by Dr. Jordan Baruch, chairman of the Industrial Advisory Committee. The report and recommendations that follow are not meant to be taken as dissenting opinions from the work of the Committee or its Subcommittees; instead they are supplemental to the goals and solutions proposed by the several components of that committee.

The specific contributions of small non-dominant businesses in the United States, when taken as a sector of the economy, are many. As will be expanded in detail in the following report, small and medium size business have been shown to be the most creative force in our economy, in terms of efficiency in the processes of invention and innovation. Such a role is essential to a business that must survive on the basis of being more competitive and aggressive than a more powerful marketplace competitor that may not react as swiftly to changing needs or conditions. However, the ability of small companies to react to just these conditions is what makes the presence of the small companies so essential to a healthy economy; as a result of new inventions and innovations, all segments of our economy—business, labor and consumers—benefit from increased opportunities, lower costs, greater choices and enhanced personal freedoms.

The work of the Industrial Advisory Committee on Innovation and Invention was initiated to explore the impact of governmental action and inaction on the ability of business to contribute to the economy. The work of the Subcommittees points out the sad fact that the work of the federal government has, in very many cases, impeded the proper functions of business as it contributes to economic growth. At the same time, it must be noted that the business sector, taken as a whole, has grown in spite of the detrimental effects of government on it.

This is not true for American small business, which, while holding its own and growing in terms of numbers, has declined in sales, assets, and market share in many different industries. In fact, the decline of smaller business over recent years may be linked as a cause to serious economic problems in the areas of productivity, employment and competition. The impact of governmental action has been especially harsh on small business, despite the best of intentions, largely because small businesses are most often treated exactly the same as major corporations in actions initiated by the government, placing an undue burden on individual small firms.

For the specific purpose of correcting these imbalances, representatives of the small business community believe it necessary to contribute the unique small business perspective to the work of the Advisory Committee, and make specific recommendations which have, as their objectives, adjustment of the imbalances affecting smaller business. A summary of these recommendations follow.

### CAPITAL ACQUISITION AND RETENTION

1. Removal of tax-code disincentives to saving and investing should be a high priority. Methods considered in the past include more rapid recovery of capital through depreciation, reduction of corporate income tax brackets, broadened use of investment tax credits, and reduced capital gains taxes. Individual taxpayers could be inspired to invest in small innovative business through the elimination of double taxation on corporate profits and dividends.

2. Allowances for immediate write-offs to research and development (R&D) expenditures need to be expanded to include all R&D spending, especially to include expenditures for the equipment and facilities used by workers in a R&D process. Also, more generous investment tax credits for R&D are needed.

3. Allow smaller businesses enhanced ability to retain key personnel through expanded stock option incentives, including: (a) increasing the qualified options time from the present five years to ten years; and (b) postpone the tax on income derived

from the exercise of non-qualified options until the shares have been sold, rather than requiring payment of the tax at the time the option is exercised.

4. Eliminate disincentives to investment in small businesses that arise through tax "penalties" that are imposed when investors move capital from a mature high risk venture into another, similar venture. This should be accomplished through provision for tax-free rollover of equity investments, or through accelerated deductibility of investments in small businesses that spend heavily on research and development.

5. Provide incentives for investors through enhanced opportunities to deduct losses incurred on investments in high-risk, research-oriented small companies. This would be accomplished through broadening the scope of qualification as a Subchapter S corporation, and through an effort to prevent the IRS from continuing to impede successful firms from deducting losses incurred through equity investments in small research-oriented businesses.

6. Encourage long-term investments in technology-based small business by creating a capital gains tax that decreases on a sliding scale to zero over a period of years.

7. Permit pension and profit-sharing funds to invest in high-return small technology businesses through modification of "prudent man" rules to the extent that a certain percentage of these portfolios may be prudently invested at higher risk with a secure return.

8. Simplify the regulations regarding the private placement of small investments and increase the SEC's Regulation A limits on the size of investment offerings without penalizing either investor or companies through regulatory compliance.

REGULATION

9. Investment in small, innovative companies would be spurred if investors could have some certainty over the future course of the regulatory environment in the industry in which the small businesses exist. To make this work, each regulatory agency should publish long-range goals, and note in particular the objectives of the agency as regards small business. In addition, procedures should be established to allow one agency to take control over rule-making and other procedures (enforcement) whenever two or more agencies are found to be developing policy in the same area or in interdependent areas, so that only one agency carries out the regulatory function, and small businesses do not need to deal with many different branches of government.

10. Innovation and invention is stifled when regulation addresses the procedures used in an industry, rather than providing goals for compliance which innovative small companies may meet in new ways. Regulations promulgated to achieve desired social goals would address output performance, rather than prescribe specific procedures that must be used.

11. Private corporations which operate in an environment of government price and entry controls are insulated form competitive marketplace pressures encouraging competition and innovation. Such controls should be eliminated, and where mandated by legislation, should be addressed through legislative authority. Entry into potentially competitive markets should be de-regulated to allow a favorable climate for the entry, growth and expansion of competitive small businesses.

12. Federal agencies should be required to study the economic impact of proposed regulations, policies and legislation prior to the time that such authorities are proposed. The studies should assess the economic impact on world markets, domestic markets, the competitive posture of U.S. industry, and the impact on American firms, large and small. A non-adversary approach should be encouraged to increase industry participation in regulations and de-regulation development.

13. Where regulation has damaged the competitive posture of small innovative business and led to increased market concentration, new economic incentives are needed to offset the cost of capital investments required to comply. It is recommended that all rule-making bodies review present regulations and incorporate in regulations a consideration of different levels of business size, and regulatory impact on these different tiers of the business community. Procedures, enforcement and paperwork requirements must be taken into account in all regulations.

14. Where small innovative businesses place new requirements on workplace safety regulations, consideration must be given to allowing small businesses to enter a market without being overly burdened at a time when it is especially vulnerable. A package should be assembled which permits workplace safety regulation relief, financing for compliance tests and liability protection, and specialized tax and impact analysis in regard to new regulations.

15. Antitrust policies that have been used to discourage innovation are inherently anti-competitive, and place an additional risk factor on ventures that are high-risk in many cases. The Department of Justice should explicitly recognize that there are certain areas in which cooperative research and commercialization of a new product or process by small business is inherently valuable, these being high-risk, high-cost "breakthrough" areas. In such cases, the participants must be allowed wide latitude in allocating the rights and benefits arising from such cooperative developments.

FEDERAL PROCUREMENT AND R. & D.

16. The federal government, as a major purchaser of goods and services, and high-technology items in particular, should be particularly supportive of innovative small businesses and their products. A change in federal procurement practice from prescriptive specifications to the use of functional specifications would provide the government with the best product to meet a given need, and would open the market to innovative business.

17. A simplified set of regulations for Federal Procurement should be developed to apply to small business. Similarly, no agency should be permitted to exclude an equal opportunity for small businesses to submit proposals for consideration on a merit basis in any program or area.

18. Small business, as the sector of the business community that innovates most efficiently, should receive a share of federal R. & D. dollars in proportion to its numbers and size in the economy. Each federal agency should be required to allocate at least 25 percent of its R. & D. funds to small businesses. In addition, a clear federal policy should be developed to prohibit federal agencies from undertaking projects competitive with or duplicative of private-sector technological development.

TECHNOLOGY TRANSFER AND PATENTS

19. To provide economic stimulus and value to taxpayers, federal research developments should be passed along to businesses that can apply them to product development. Legislation should be passed to give title to an invention to a government contractor that develops it, provided that the contractor undertakes commercial application of the invention. If, in a reasonable time, such application is not made, title would revert to the government, which should undertake to license such inventions on an exclusive basis, preferably to small businesses. Likewise with inventions made in national laboratories or under government funding, the government should preferentially license small businesses.

20. The quality and quantity of innovation in this country may be significantly upgraded via improvements in the system of patent protection. As a first step, it is necessary to improve the reliability of the Patent and Trademark Office, and provide funding sufficient to insure that examinations made by that agency are accurate and thorough. Second, as patents are a keystone in the commitment of funds to carry out commercialization of a new product, patents should be rendered incontestable after a certain period of time. Finally, a workable system for technology transfer needs to be developed through the Patent and Trademark Office, so as to put to use "blocking patents" that are not commercialized after a period of time. Consideration should also be given to providing information to small business in much the same way as the agricultural extension service provides information to the agricultural community.

21. The growth of invention and innovation, and thereby the growth of the economy, depends on an adequate supply of individuals motivated to develop the capability to generate and synthesize information relating to needs, opportunities and knowledge. People, not institutions, are innovators. Programs must be developed to identify individuals having the ability to innovate, to teach innovation, and to provide support where it is necessary. Most importantly, there should be a practice of providing rewards to employed inventors and to small businesses that generate new inventions and commercial applications.

## Small Business Views With Regard to Invention and Innovation

(A report by Eric P. Schellin, Esq., Chairman, Board of Trustees, National Small Business Association, Executive Vice President, National Patent Council)

James Ronaldson, the first President of the Franklin Institute wrote in 1833: "The objects of the Franklin Institute are to develop the resources of our country; to throw all the light possible on the processes of industry, and *to make the bringing of the products into market as simple as the nature of the case will admit;* to cultivate whatever is calculated to make a demand for labour, and the employment

of all according to their respective capacities and means, to the end that there should be none who shall not be in enjoyment of the necessities and comforts of life." (Emphasis supplied.)

The above quotation clearly demonstrates that creative invention and the follow up innovation have long been desirable achievements in our industrialized society.

Facilitating the bringing of new products to market simply and efficiently concerns small business in this report. While the act of creating an invention is of great importance, it constitutes only ten percent of the effort to bring new products to market. The other ninety percent constitutes the efforts to achieve innovation. As Edison observed, bringing a new product or process to commercial fruition is one part inspiration and ninety-nine parts perspiration.

In mid-1978 President Carter ordered a thorough review of the impact of policies of the federal government upon industrial innovation. The President directed Secretary of Commerce Juanita Kreps to supervise this study, and she in turn appointed an Industrial Advisory Committee to work under the direction of Dr. Jordan Baruch, Assistant Secretary for Science and Technology. This Advisory Committee of more than one hundred business executives was divided into seven subcommittees to analyze specific areas of federal policy and their impact on private-sector decision-making relative to innovation.

It was unfortunate that most members of the subcommittees were from large, well-established corporations. At least, to the credit of the selectors, each group included at least one individual from small business who participated actively in the work of each subcommittee and made contributions to the reports that have now been produced. Of course, the exceptions to this, as would be expected, were the subcommittees of Labor and the Public Interest.

Upon completion of the reports of the several subcommittees, many of the small business representatives agreed that an additional report should be prepared. The purpose: to incorporate in a more positive manner those recommendations of small business and include those recommendations that had been ignored in the reports partly due to under-representation by small business on the various subcommittees. That is not to say that small business is in disagreement with most of the subcommittee conclusions. On the contrary, small business is in agreement with most of the conclusions and recommendations of the seven subcommittee reports. Nevertheless, it is our conclusion that we would be remiss to the small business community to bypass the opportunity to provide our carefully formulated recommendations. The following statement is not a minority position to express disagreements with any of the subcommittee reports, but is designed to prioritize some of the recommendations according to the small business view and to serve as a supplement to address the unique role and unique problems of small innovative enterprises in America.

It has always been a policy of government to achieve a societal impact by means of legislation and application of government to accomplish a perceived goal. Therefore, tax laws are extant that not only provide for the functioning of government but also undertake the redistribution of wealth for the benefit of a defined class. Tariff laws are designed to assist individual industries. In agriculture, laws have been conceived and applied to provide underpinnings to particular farmers. These and many other governmental incursions for the benefit of an identified group are said to formally benefit all of society.

Until the passage of a graduated corporate income tax in 1978, there had been little recognition of small business as a defined class. Yet, as will be discussed hereinafter, small business has been recognized to be the cutting edge of competition, at the forefront of innovation, and a sane counterweight to the competing forces between big business, big labor and big government. To achieve increased market entry, increased innovation, and catch-up growth, there should be absolutely no question that a two-tier policy must be a societal goal, in which small business is treated differently than big business. There should also be no question that an applied two-tier policy will achieve beneficial social growth.

### A TWO-TIER POLICY PROVIDES A FAVORABLE SOCIETAL IMPACT

Inflation has become our most crucial domestic problem. Inflation is believed by the small business community to be not only the result of a number of conditions but also a direct result of a major decline in private sector innovation over the past decade. The driving force to real economic growth is innovation that results in increased process productivity and in the introduction of new products and services to the economy. Without innovation, economic stagnation occurs. With vigorous innovation, there is an increase in real income; job opportunities are expanded; exports are increased; our currency is strengthened; productivity is increased; and,

as a long-term result, there is more opportunity to finance achievements in such qualities of life as education, health care, longevity and leisure. Furthermore, to a large extent, small business believes that ambitious social goals of Americans can be obtained only from real economic growth that in turn can only occur as a result of vigorous private sector innovations.

In support of our conclusion, we will examine three premises:

A. Small businesses make a disproportionately large contribution to innovation.

B. Small innovative businesses create jobs at a more rapid rate, thereby increasing tax revenues.

C. The creative process in small business is highly sensitive to governmental policies.

*A. Small businesses make a disproportionately large contribution to innovation*

The economic history of the United States is replete with examples of the small business innovator making a major contribution. A recent study conducted for the National Science Foundation concluded that firms with less than one thousand employees in the post-World War II period were responsible for approximately fifty percent of the "most significant new industrial products and processes," and firms with one hundred or fewer employees produced twenty-four percent of such innovations. In addition, it has been discovered that the cost per innovation in a small firm is about one-half that in a large firm. This does not mean that small, innovative businesses should be expected to do everything—there is much innovation that only can succeed in large companies. However, in many cases, small firms are more adventuresome and willing to take on greater risks; in other cases, they, because of their flexibility, are able to be more responsive and use resources more efficiently. It is small business' contention that there is something fundamental and basic about the unusual ability of small firms to innovate that must be preserved for the sake of healthy economic and social growth.

"An examination of American business history from the late 1700's through 1970 shows that a major source of technological advancement has resulted from the work of individual inventors and individual entrepreneurs working independently of big business. This is particularly true where radically new concepts have been invented and introduced. The great inventors in American history were also innovators."

In 1793, we had Eli Whitney with his cotton gin, and Robert Fulton with the steamboat in the 1800's. We all know that these two innovations had an enormous impact on young America. Later came the railroads. Next, in telecommunications, we had Morse and Bell, whose contributions greatly accelerated the growth of our economy. Similarly, the Wright brothers, McCormack, Edison, Westinghouse, Ford and DeForest made introductions that laid the foundation for further economic advances. This is obviously only a partial list. All of these innovators were entrepreneurs.

The same trend continued after World War II with the success stories of Edwin Land at Polaroid and Watson at International Business Machines. During the 1960's we saw the emergence of companies such as Xerox, Control Data, Digital Equipment and Hewlett-Packard, each beginning as individual small business entrepreneurs with their small companies who were unfettered at that time and therefore able to innovate. In addition to these better known names, there were thousands of small, lesser known, high-technology companies spawned during the 1950's and 1960's that have created real growth in our economy and increased the quantity and quality of employment.

*B. Small innovative businesses create jobs and taxes at a more rapid rate*

The role of small innovative businesses in stimulating economic growth also can be seen from two recent independent studies on employment. The first, by the Massachusetts Institute of Technology Development Foundation, shows compounded average annual growth from 1969 to 1974 for the following three groups of companies:

| | In percent | |
|---|---|---|
| | Sales | Jobs |
| Mature companies | 11.4 | 0.6 |
| Innovative companies | 13.2 | 4.3 |
| Young high-technology companies | 42.5 | 40.7 |

In this study, mature companies were Bethlehem Steel, DuPont, General Electric, General Foods, International Paper, and Procter & Gamble. Innovative companies were Polaroid, Minnesota Mining and Manufacturing, International Business Machines, Xerox, and Texas Instruments. Young high-technology companies included Data General, National Semiconductor, Compugraphic, Digital Equipment, and Marion Laboratories.

The Massachusetts Institute of Technology report states:

"It is worth noting that during the given year period the six mature companies with combined sales of $36 billion in 1974 experienced a net gain of only 25,000 jobs, whereas the five young, high-technology companies with combined sales of only $857 million had a net increase in employment of almost 35,000 jobs. The five innovative companies with combined sales of $21 billion during the same period created 106,000 jobs."

It should be noted that the House Small Business Committee in its 1978 report on "Future of Small Business in America" stated that small business between 1969 and 1976 "accounted for what can be considered virtually all the new private sector employment in this country." The companies in the "Fortune 1000" contributed less than 2 percent of the growth in new jobs.

Similar conclusions emerged from a study of 269 firms by the American Electronic Association. In February of 1978 Dr. Edwin V. Zschau of the AEA presented the conclusions of that study to the Senate Select Committee on Small Business. The report showed the following growth of employment for newly-established firms as contrasted to more mature companies:

| Years since founding | State of development | Employment growth rates in 1976 |
|---|---|---|
| 20+ | Mature | 0.5 |
| 10 to 20 | Teenage | 17.4 |
| 5 to 10 | Developing | 27.4 |
| 1 to 5 | Startup | 57.7 |

Dr. Zschau also reported that annual benefits to the economy realized in 1976 for each $100 of equity capital that had been invested in start-up companies founded between 1971 and 1975 were:

| | *Per year* |
|---|---|
| Foreign sales | $70 |
| Personal income taxes | 15 |
| Federal corporate taxes | 15 |
| State and local taxes | 5 |
| Total taxes | 35 |

This data shows that the benefits of investment in small innovative ventures are large (e.g., a new $35 per year flow in tax revenues for each $100 initial investment) and that this flow of benefits starts soon after the investment. These benefits are large and powerful.

The benefits from a climate for favorable small business innovation is apparent from this review of the contributions to the past and recent economic growth of our country by individual entrepreneurs in their small companies. If we are to continue to enjoy the benefits of innovation, then individual entrepreneurs and their small business must be able to carry a very large share of the burden of innovation.

Unfortunately, the climate today for the formation and nurturing of small innovative businesses is not good. Although there is not a concise index of innovation, particularly innovation by individuals and their small businesses, we are certain that such an index would show a substantial drop in innovative contributions of small business over the past ten years—probably a decline to a level of ten percent of the average from 1950 to 1970, if not lower. Furthermore, if one takes as a parameter of innovation the factor of unassigned patents and excludes assigned patents to big business, it is quite obvious that the proportion of patents going to individuals and small business is declining.

*C. The creative process in small business is highly sensitive to governmental policies*

Creative processes in small business have many dissimilarities with the creative processes in large corporations. The first step involves the use of knowledge (market, scientific, sociological, etc., alone or in combination) to conceive a new product or service. The second step is to reduce this conception to practice through the construction of a first prototype (or some other form of initial trial), often on a small scale in the laboratory. If technically and economically promising, the new product or service is put into initial full-scale production and distribution. With success, production is expanded until the firm and its market matures, and significant employment and tax revenues are then generated.

Until successful production is achieved, the process is usually a struggle for the entrepreneur manifesting itself in a number of ways: A struggle to obtain adequate capital; a struggle to make the technical breakthroughs that are necessary to overcome the seemingly never-ending emergence of unexpected obstacles; a struggle to keep development costs and initial production costs low; a struggle to collect amounts receivable and other payments in time to meet the next payroll; and a struggle to acquire and motivate capable scientific, engineering, production and management talent.

Outside factors, such as goverment interference and delays, substantially compound these roadblocks, decrease creativity, and increase the risk of failure. With increased risk, capital allocation decisions are made in favor of alternate, safer investments, often of a short term nature; entrepreneurial motivation is demoralized; and many innovative ventures are not undertaken. This unwillingness to undertake is of great concern to small business, and must be to our entire economy, as well.

The availability of initial "seed" capital (for making the concept a reality), start-up capital (for the first production), and capital for expansion is an essential and often limiting link in the small business creative process. Federal tax and security exchange policies are major determinants throttling this flow of capital to small business investors.

The impact of such federal policies is widespread. In addition to limiting the availability of capital, the federal tax structure is a major determinant in the ability of young companies to retain sufficient earnings to finance early growth. Regulatory policies detract from the creative entrepreneurial process and lessen the chance of success. Federal research and development policies, and procurement policies, can either stimulate or inhibit the small business innovative process, and patents and other policies providing exclusivity can provide the struggling entrepreneur with the necessary protection to put inventive technology into profitable production.

## SOME GENERAL CONCLUSIONS

From participation in this study of industrial innovation, several general conclusions have been drawn by small business:

1. Innovation by independent entrepreneurs and their small businesses is essential for health economic growth, since a large contribution is made by small innovators.

2. A wide range of federal policies are having serious deleterious impacts upon the ability of small businesses to innovate, to begin operation and to survive.

3. The fundamental reason for the decline in small business innovation is the failure of government policymakers and administrators to recognize that small firms, particularly small innovative firms, cannot accommodate governmental burdens as readily as can large companies. The burden of government interference on small innovators is disproportionately large and often overwhelming.

4. Until government recognizes the critical nature of this overwhelming burden, and until adequate amendments to domestic policies are accomplished, it is believed that innovation by small enterprises will continue to be strangled. These amendments to domestic policies must establish and implement a two-tier system for dealing with small business in a different manner of procedure and substance, than with big business.

## SPECIFIC RECOMMENDATIONS

There are four broad scope areas of policy recommendations which have been developed specifically for small business. These recommendations are identified as follows: (1) Capital acquisition and retention. (2) Regulation. (3) Federal procurement and R&D. (4) Technology transfer and patents.

CAPITAL ACQUISITION AND RETENTION

The availability of seed, start-up, and expansion capital for small innovative enterprises is a major factor determining the rate of innovation. Unfortunately, significant changes have occurred during the past decade in taxation policy, security exchange and pension regulations, and in investment management policy that are inhibiting the flow of capital into new, innovative businesses. It is hoped that the following group of recommendations will be implemented to provide incentives to small local inventors throughout America, and to again provide seed and start-up capital to promising innovative ventures by (1) ameliorating tax and security inhibitions; and (2) providing tax incentives for such investments that are similar to those now available for competitive opportunities in retirement savings plans and real estate.

*Issue No. 1*—Tax Code now favors spending rather than saving

It is believed that the removal of disincentives to savings and investment should be the primary purpose of tax policy designed to encourage innovation. Tax policy is the only means at the disposal of the government that can have anywhere near the required impact. In the process of debating the last federal tax reform bill, the Congress and the Executive Branch considered several different policies, each of which would have this effect. Among them were allowing for more rapid recovery of capital through depreciation, lowering corporate income tax rates, enhancing the investment tax credit in numerous ways, and lowering rates of taxation on capital gains. Rapid recovery of capital through depreciation would be the most cost-effective way of encouraging innovation and its application by newly established industries. Such measures as elimination of the double taxation of corporate dividends and lower taxes on capital gains would provide more incentive to savings by individuals.

*Recommended Action*

Increase overall incentives for savings by individuals and investment to be established through use of the tax code.

*Issue No. 2*—Providing for immediate writeoff of all R&D expenditures

Present law permits salaries, wages, material and supplies in R&D to be deducted as incurred, even though the benefit of such expenditures may only be realized at some time in the future. Many western countries, including Canada and W. Germany, currently allow expenditures for the equipment and facilities used by these workers to be immediately written off as well. Permitting this practice in the U.S. would not only increase corporate cash flow and improve the incentive to make such expenditures, but it would also make R&D capital expenditures relatively more attractive than other capital expenditures, thereby providing an incentive for corporations to channel a larger proportion of their investment dollar into R&D activities.

Additionally, by increasing for small business the investment tax credit, there would be a channeling of a larger portion of the small business investment dollar into R&D capital equipment by creating a greater incentive in that area. It would be particularly helpful to small businesses for which research expenditures form a substantial portion of the annual budget, and would thereby provide the largest portion of its benefits to firms engaged in disproportionately large amounts of innovation.

*Recommended Action*

Allow the immediate writeoff of all R&D expenditures, properly defined, including those for facilities and equipment. Failing that, allow a three or five year writeoff for facilities and equipment, comparable to the special depreciation rules now being applied to capital expenditures for pullution control facilities. In addition thereto, a larger investment tax credit should be permitted for those capital expenditures that are research related and there should be permitted a research tax credit for those research related expenditures not now eligible for the investment tax credit, allowing for appropriate carry back and carry forward provisions.

*Issue No. 3*—It is difficult for small technically-oriented businesses to retain key personnel

It has been noted with small, highly technically oriented businesses that it is a problem and a struggle to retain key personnel. It is believed that this problem will become exacerbated as the American economy enters a period of scarcity in trained and competent engineers. Frequently, the only material incentive that a small business can offer to the would-be inventor or would-be participating entrepreneur,

either to the founder or a key member of the team, is the promise of wealth through a substantial multiplication in value of the stock of the company.

*Recommended Action*

For small businesses, which spend more than an established percentage of revenues on research and development, allow more favorable stock option incentives to founders and key personnel by (a) increasing the qualified options time from the current five to ten years and (b) postponing the tax on income derived from the exercise of non-qualified options until the shares have been sold rather than paying the tax at the time the option is exercised.

*Issue No. 4*—Tax consequences of withdrawing investments in small business enterprises are formidable

These consequences are now so severe that many potential investors stay away from investing in the first place, believing that the risks of such investment are not justified by the potential after-tax reward. The net effect is, of course, to discourage the number of investors interested in such high-risk investments. There should be a tax-free rollover provision which would eliminate this difficulty, permitting capital to move from one small business as it matures to another without adverse tax consequences. Another method of attracting new capital to investments in small or new venture companies would be to permit immediate write-off of initial capital investments to zero even though it would result in a larger capital gains tax eventually. The appeal of such immediate "tax shelter" to individual investors has been well demonstrated.

*Recommended Action*

Permit tax-free rollover of equity investments or—alternately—immediate or accelerated deductibility of initial investments in small businesses, which spend more than a given percentage of revenues on research and development.

*Issue No. 5*—New small businesses typically are characterized by substantial losses in their early years of operation

Section 1244 of the Internal Revenue Code and Subchapter S laws allow losses in businesses covered by these laws to be passed through to investors, thereby making these businesses more attractive to those investors who are in a position to sustain losses on their investments as an offset to other income. The qualifications for Subchapter S treatment, however, are such that few ventures qualify. The treatment afforded under these provisions of the tax law should be more generally available. In the same context it should be made easier to buy and sell corporate tax losses. In recent years IRS rulings have made it increasingly difficult for tax losses resulting from an unsuccessful venture to be used by a more profitable acquiring company. The effect is to deprive the investors in the unsuccessful venture of their right to recoup some of their losses through sales to a more profitable company.

*Recommended Action*

Allow start-up operating losses to flow through to founding investors in small businesses which spend more than a certain percentage of revenue on research and development.

*Issue No. 6*—If the tax-free rollover provisions on the exemption of small business investments from capital gains taxes cannot be achieved, consideration should be given to reduced or zero tax rates for investors who invest in small or venture capital businesses over long periods of time

Incentives to long-term investing are especially desirable in financing new ventures which require long term horizons to each fruition. Under an appropriate plan, capital gains taxes on sales of small business investments would gradually decrease to zero over a period to time, perhaps five years.

*Recommended Action*

Create a sliding scale tax rate for longer term investments in those small businesses which spend more than a given percentage of revenues on research and development.

*Issue No. 7*—ERISA and various state regulations have had the broad effect of making institutional managers of fiduciary capital even more conservative by requiring that prudent man concepts guide each individual investment decision

It should be within reason for a "prudent man" to invest a small but meaningful portion of his investment portfolio in venture capital enterprises. Amending the definitions of "prudent man" embodied in various regulations in such a way as to

allow institutions to apply it to their overall portfolio instead of to each investment would encourage investment in small growth companies and venture capital. Likwise, regulations and legislation affecting banks, insurance companies, savings and loans, state credit unions, and state retirements systems all tend to restrict rather than enhance the availability of venture capital.

*Recommended Action*

Modify the concept of the "prudent man" that has been embodied in government regulations so as to allow institutions to hold a certain percentage of this investment portfolio in small business venture capital. Also encourage states to liberalize the investment restrictions on state-regulated pools of capital so as to allow investment of some portion of these funds in equity positions or venture capital firms specifically for small business.

*Issue No. 8*—Regulations regarding private placement of small investments and the size of Regulation "A" placements are too restrictive

In April 1974 the SEC adopted Rule 146 under the Securities Act of 1933, in an effort to reduce and clarify the nature of the requirements for the private placement of small investments of the kind that are typical of venture capital opportunities. That rule has not achieved the goals intended. Additionally, Reg. A imposes a flat dollar limit on the amount of money that can be involved in an offering without becoming subject to all of the limitations imposed by the regulation. This limit is in need of further upward adjustment in order to take into account the effects of inflation over time. It would be salutary to widen the availability of start-up losses of small innovative businesses to be used as deductible expenses to investors.

*Recommended Action*

Simplify the regulations regarding the private placement of small investments and increase the SEC's Regulation A limits on the size of investment offerings.

REGULATION

During the past decade, a new regulatory environment has emerged to fulfill a variety of social "mandates." This new regulatory environment includes agencies such as OSHA, EPA, CPSC, NTSB and EEOC, in addition to expanded jurisdictions of existing agencies or departments such as FDA, U.S. Corps of Engineers, SEC, FTC, Justice Department and others involved in the regulation of business in one way or another. The mission of each of these agencies is well intended and, if only one (or a few) of them were impacting upon small innovative businesses their impact could be absorbed within the creative process. Unfortunately, for many small businesses there is involvement with a wide range of agencies and, in some cases, the laws and regulations enforced were intended for some other purpose than the new field being pioneered by the innovator. There are even cases of conflicting regulatory authority and requirements.

This emergence of widespread regulation requires a major drain of time, capital and energy. It contributes to a substantial interruption of the creative process and an increase in the risks of undertaking new ventures. It causes diminished market penetration. As a result, the economic make-up of the U.S. is being distorted in favor of those fields where regulation is minimal. Entrepreneurial involvement in those fields where regulation is diverse and intense is greatly reduced and innovation, therefore, is diminished.

It is unfortunate that this adverse regulatory environment has caused many small innovators to consider the federal government to be an alien power committed to their destruction.

*Issue No. 9*—Lack of predictability of regulation reduces innovation

Changing objectives or uncertain standards of regulation, as well as uncertainty in the methods for measuring compliance, act as barriers to innovation. Small business is especially vulnerable when regulation by the same or different regulatory agencies is contradictory or when standards or methods of measuring compliance are not stabilized for a sufficient period of time. Thus a great many small businesses are not willing or able to accept the risk of committing resources on an innovation. The result is a reduction of competition.

*Recommended Action*

1. Each regulatory agency should issue a long range statement of regulatory intent that could serve as guidelines for both the agency and the regulated. Such a statement of intent should take into consideration whenever applicable any special circumstances found in regard to small business.

2. Whenever two or more agencies are developing regulations or policy on a single issue or interdependent issues, an interagency coordinating committee should be formed to assure consistency. Whenever possible, there should be a consolidation of regulation to prevent over-regulation (especially of small business) so that only one single agency carries out the regulatory function.

*Issue No. 10*—Innovation is stifled by regulating the means rather than the results

Regulations resulting from then adoption of new social enhancement regulations have too frequently not been goal-oriented. Rather than requiring a specific defined output in a manufacturing plant's effluents, for instance, the regulations control the industrial processes themselves. Such regulations on processes prohibit innovation as a means of achieving the required goals. Importantly, such so-called input regulations inhibit competition and maintain the status quo of industry structure as small business is thwarted in attempting to penetrate and develop a market.

*Recommended Action*

Regulations promulgated to achieve desired social goals should be limited to output performance. They should not dictate the processes used by industry to achieve the standards. Such a refocusing of regulations would foster innovation both in meeting the standards and would encourage entry of additional businesses into the market, especially by small businesses who would approach compliance in a creative manner.

*Issue No. 11*—Regulation of price and entry impedes innovation

Price-controlled corporations, which are almost always large businesses, whose prices and entry are regulated by government, have no incentives for departing from the status quo, thus retarding innovation and thereby entry by new small businesses. Government price and entry controls distort market forces and hence influence both industry structure and competition. Private corporations which operate in competitive or potentially competitive markets where prices are controlled by government are insulated from the innovation-encouraging pressures of marketplace price competition. The nation and the consumer would be better served if price and entry regulation of competitive industries were removed so that market oriented innovation, which are the natural result of competitively-determined market prices, could flourish.

*Recommended Action*

Governmental price and entry controls of products or services provided in competitive markets should be rapidly eliminated. Where such controls are required by legislation, initiatives to modify the legislation to eliminate governmental control should be introduced and actively pursued. Entry to potentially competitive markets should be de-regulated, thereby providing a favorable climate for small business expansion.

*Issue No. 12*—Unconsidered economic impact of regulation impairs industry viability and weakens world market positions

Governmental regulatory agencies are not presently required to account for the effect of their regulations on the competitive position worldwide of the industry being regulated. In addition, the government's role vis-a-vis industry, especially small business, should be examined. Government repeatedly demonstrates a lack of knowledge of the nature and problems of small business, in contrast to the cooperation between government and industry evidenced in Europe and Japan.

*Recommended Action*

In considering and establishing regulations, policies, and even legislation, U.S. government agencies should be required to study the impact of their actions upon the worldwide competitive posture of U.S. industry. A non-adversary approach should be encouraged via directives to the regulatory agencies to increase industry participation in regulation or de-regulation development.

*Issue No. 13*—Costs of regulation lead to increased market concentration

Smaller firms, historically the source of significant contributions to innovation, suffer disproportionately greater injury from the overall costs of regulations than do larger firms. Hundreds of smaller firms have had to close due to costs of compliance with new regulations and, as a result, larger firms once dependent upon them as suppliers have been forced to either enlarge their existing operations, or integrate vertically. The natural growth objective of big businesses, compounded by the effects of inflation and the double tax on dividends, creates a demand for performance

which, in many cases, can only be met by supplementing their core business growth with acquisitions.

*Recommended Action*

New economic incentives are needed to offset the cost of capital investments required for regulatory compliance. Such incentives are needed not only to inhibit the unintended destruction of small innovative firm but to encourage the establishment of new small businesses.

To correct the present inequities of the costs of compliance with regulations imposed on smaller business, it is recommended that all rule-making bodies review present regulations, as well as to incorporate in all new regulations a consideration of different levels of business size. While substantive requirements should ordinarily be uniform for all size levels, procedures and paperwork required for compliance should take into account these variations in business size.

*Issue No. 14.*—When safety regulation in small business is accomplished with a heavy hand it defeats the market entry at a time when small business is particularly vulnerable

Due to the large role the small business has played in innovation some special attention should be given to small business which by its very nature will be facing new situations on workplace safety, environmental effects and product safety.

Accordingly, it would be wise to provide for workplace relief from inspections which would be based on an inspection scheme that emphasized self-development of safe practices. Once an emerging business category was fixed, it would be excluded from usual treatment until a significant deviation from inter-industry norms developed or probable cause has been observed. Size should be fixed by firm demographics in the industry, but critical size would be larger than the ten person level considered but not enacted in the last Congress. It should be noted that the concept does not mandate exceptions but does require a show-cause approach.

Also, consideration should be given to providing funds for compliance tests and liability insurance. The latter may be achieved sometimes by providing tax relief on the funds set aside by way of self-insurance. If regulatory practice, in effect, establishes barriers to market entry as has frequently occured, then some remedy should be available. This would necessitate for expansion of the present small business loans program or, as an alternative, outright grants.

In view of the recognized need for compliance, small business today is faced with many more expense hurdles than heretofore. Therefore there ought to be an opportunity to expense venture expenditures in the year they occur. An established company can expense its expenditures against sales. A venture company will freqently go through a stage where expenditures exceed sales and must therefore be supported out of capital. To encourage venture investments, the residual owner shares of these expenditures should be made allowable tax deductions.

Another area should be the provision that a small business impact statement be issued when new regulations are proposed, and that such impact statements be subject to administrative fact-finding and judicial review before their adoption. It is especially important that attention be given to this area by study before implementation of the regulation, as opposed to after.

*Recommended Action*

Due to the potentially large role that small firms have in innovation, a package should be assembled which permits workplace safety regulation relief, financing for compliance tests and liability protection, and specialized tax and impact analyses in regard to new regulations.

*Issue No. 15*—Antitrust policies can inhibit innovation

It is recognized that the antitrust laws do not directly address innovation. Rather innovation is generally stimulated by competition. It may be postulated that antitrust policies which foster competition tend also to promote innovation. Insufficient attention, however, has been given by the Congress, the antitrust enforcement agencies and the courts to the converse proposition: antitrust policies which discourage innovation are, to that extent, inherently anti-competitive.

Innovation itself is inherently a high risk proposition: the costs are substantial, the prospects uncertain; by definition, it involves the unknown. When other risks (such as the risk of provoking antitrust actions) are superadded to the equation, or when the prospect of reward is unduly circumscribed, the scales may tip toward the safer course of risk-avoidance. Moreover, because the antitrust rules are imprecise, plus the fact that they are unfairly applied predominantly against smaller business

as being more easily intimidated defendants, the business decision-maker has difficulty in assessing the likelihood of adverse action or the magnitude of exposure.

*Recommended Action*

While the conduct of research projects on an individual firm basis, or among firms which are not competitors, is ordinarily to be preferred, the Department of Justice should explicitly recognize that there are certain areas in which joint or cooperative research and commercialization among small businesses should be encoraged. This is especially true in the case of high-cost, high-risk "breakthrough" oriented projects. The generally procompetitive long-term effects of major innovation should ordinarily be given great weight. Also in such cases, the participants should be permitted wide latitude in allocating the intellectual property rights and other benefits which are the products of the research, where such allocations are in fact ancillary to, and supportive of, the legitimate purposes of the research.

FEDERAL PROCUREMENT AND R. & D.

The federal government is a huge purchaser of goods and services. the rules and regulations by which procurement occurs affect the ability and incentives for government contractors to innovate. Changes should be initiated to encourage greater participation by the highly innovative small business sector.

*Issue No. 16*—Procurement of innovative common use items

On the surface it would appear neither logical nor reasonable to advocate that the federal government play a leading role in the development of new technology for common use or consumer type items. However, it is entirely sensible to suggest that the federal government—as a major purchaser—should be supportive of small innovative businesses and their products. Much that occurs in the federal government's current procurement practices suggest that thei role is exactly the opposite.

The innovation that occurs in the portion of the economy concerned with the production of common use items is generally stimulated by the commercial marketplace. A company develops new technology and products because of its desire to maintain or increase market share and profitability. Despite the magnitude of the federal market, it is rarely available for innovative new products. Unfortunately, the cost of development of the new technology in the early years of an innovative product life cycle must be supported solely by the commercial market.

A prescriptive specification in a low bid procurement is the present method used by most contracting officers to reduce risk. It generally prevents the proper evaluation of new products and their subsequent purchase by federal government agencies. This methodology stifles innovation and creativity on the part of successful contractors.

*Recommended Action*

Federal procurement should be approached whenever possible with regard to common use items from a functional standpoint.

*Issue No. 17*—Small business continually feels frustrated in dealing with Federal Government contractors

There is little question that big government prefers to work with big business. Big business has the ability to amortize the cost of understanding federal government regulations connected with major contracts over long periods of time. The federal government prefers dealing with someone who understands the regulations and is aware as to how to go about conforming to them. The average small business is naive about the demands of the regulations and is not consistently available for contracts. As a result the average small business builds up little expertise; nor can it easily afford to purchase such expertise on the possible premise of obtaining a government contract.

Most small businesses have experienced a tilt in favor of big businesses as evidenced by an inability to discover necessary information to enable small business to bid, thereby being excluded from large areas.

*Recommended Action*

A separate simplefied set of Federal Procurement Regulations should be developed to apply to small business. Similarly no agency should be permitted to exclude an equal opportunity for small business to submit proposals for consideration on a merit basis in any significant program or area.

*Issue No. 18*—Small business does not obtain anywhere near its proportionate share of Federal R. & D. funds

The federal government has a major commitment to non-defense research and development that is conducted at federal laboratories, at universities, and in the private sector. In many cases, this commitment to the development of scientific knowledge has made substantial contributions to technoloical innovation. As stated at the outset and by many others, small business enterprises have historically made a disproportionately large contribution to innovation and such contributions are often at substantially lower costs. Due to the proven effectiveness of small businesses to innovate when provided with the proper incentives, and because of the proven low cost of small business innovation, it is appalling that greater use is not made of this effective and efficient sector of the research community.

*Recommended Action*

Each federal agency should be required to allocate at least 25 percent of its R&D funds to small business. A clear federal policy should be established and enforced to prohibit federal agencies from engaging in and supporting research and development projects that are competitive with or duplicative of private sector technological developments.

## TECHNOLOGY TRANSFER AND PATENTS

The importance of information that is technological in nature and the transfer thereof as a driving force in innovation is well known. Knowledge provides the basis for invention and innovation; information is knowledge communicated, and it follows that information about processes, science, technology, markets, etc., is the stimulant for innovation. One of the principal roles of government in this age of electronics, computers, and space exploration has been to help tap the reservoir of scientific and technical information available worldwide and deliver it to scientists, innovators and small business entrepreneurs, directly and with the aid of the private sector. It is not surprising that there is no shortage of the raw materials that make up the information stream. Patents, data, documents and literature are superabundant. It is more than likely that the documents containing the results of this intellectual effort do not reach the total audience that can capitalize on the contents. In the absence of such communication, innovation is hobbled. Besides the purely scientific aspects, it is equally important that businesses, especially small businesses, and governmental agencies, especially at the local level, have access to information about managerial and procedural innovation which may be simply new and better ways of doing things.

In the context of information, the patent system in this country serves two broad purposes. First, it spurs invention by protecting the intellectual property of the inventor who has hopes of economic rewards; and second, it requires disclosure of inventions and so diffuses information. However, it is important to note that the patent system includes only a portion of the inventions that might give rise to innovation. It omits an increasing number of important developments, either because they are not patentable or because the inventor has lost confidence in the patent system and chooses not to obtain patents. Furthermore, the system does not cover trade secrets, systems innovations, marketing innovations, or innovations in management organization and implementation, all of which have important implications for the innovative process.

*Issue No. 19*—The Federal Government as a result of contracts with private companies possesses a great number of patents that may have commercial application

Experience has shown that the government, as a purchaser or consumer of goods and services, is not in a position to take advantage of its ownership of patents to promote enterprise. Private companies, on the other hand, who are in a position to utilize the patent grant are ordinarily unwilling to take a nonexclusive license under a government-owned patent and commit the necessary funds to develop the invention, since it has no protection from competition. This is a major reason that over 90 percent of all government patents are not used.

The idea that what the government pays for belongs to the people is not only appealing, it is true. The question is: What instrumentalities can be brought to bear to maximize the possibilities that the people will indeed have available the fruits of their government's expenditures? Non-exclusive licenses to undeveloped inventions, offered by the government or anyone, have few takers, whereas patent ownership or exclusive licenses or sufficient duration are much more likely to attract the money and the talent needed to make and market real products to meet consumer needs.

If the results of federally-sponsored R&D do not reach the consumer in the form of tangible benefits, the government has not completed its job and has not been a good steward of the taxpayers' money. The right to exclude others conferred by a patent, or an exclusive license under a patent, may be the only incentive great enough to induce the investment needed for development and marketing of products. Such commercial utilization of the results of government-sponsored research would insure that the public would receive its benefits in the form of products and services, more jobs, more income, etc. the cost of government funding will be recovered from the taxes paid by the workers and their companies, especially with regard to small business, which has demonstrated an excellent track record.

*Recommended Action*

Legislation should be passed to give title to an invention to a government contractor, with the provision that commercialization of the invention be undertaken in a reasonable time. If such commercialization is not undertaken, the title should revert to the government and the government should offer exclusive licenses, giving small businesses preference. Likewise, with regard to inventions made in the national laboratories, the government should preferentially license small business.

*Issue No. 20*—The patent system provides both the encouragement to disclose innovative ideas by, in return, providing the innovator with temporary exclusivity to make, use or sell, and importantly, also provides the source material for technology transfer

There is a consensus that in general the patent system has served the country well. However, the most serious problem with the patent system is the uncertainty about the reliability of the patent grant. Before granting a patent, the Examiner in the Patent and Trademark Office undertakes a search through the prior publications available in order to determine whether the same or like invention has been disclosed. These prior publications consist of over 4,000,000 U.S. patents, a like number of foreign patents and an untold number of literature references. Including cross-references, there are close to 20 million documents. The prior art thus available constitutes the world's greatest source of technology and is a repository for almost all scientific knowledge. However, this body of knowledge is only useful when it is available, i.e., not misplaced or missing and means are provided for ready accessibility both for the Examiner and outside innovators.

If in the course of the search for pertinent prior art the Examiner does not find art that is said to anticipate the claimed invention, the Examiner will permit the application to issue into a patent. However, if the art is not available to the Examiner because it is missing or the repository is not sufficiently extensive, a good prior art reference may have been overlooked. Should a patent get into litigation, the party opposing the patent holder will usually authorize a very extensive search to redo what the Examiner has done in an attempt to obtain better prior art. It is sad to note that most of the time better art will be discovered. As a result, the exclusivity afforded by the patent grant is emphemeral; that is what is meant by unreliability.

The Patent and Trademark Office realizes that it does not, due to budgetary restraints, possess the proper resources to provide the requisite information to its own examining corps nor does it possess sufficient information to engage in a good technology transfer program. As a result, the Patent Office has consistently put more and more of the examination process on the applicant and, when it is small business, it is that segment that can least afford it. The office has degenerated into a de facto registration patent system where the patent holder obtains a patent of questionable validity and merely posseses a license to sue.

One of the ways to encourage investment to complete the innovation process by commercializing inventions is by reducing the risks involved in decisions to commercialize. The risks of commercializing inventions can be reduced if the inventions are the subject of reliable patents and if uncertainties relating to the utilization of patent rights can be resolved quickly and inexpensively. Also, the availability of reliable patents encourages decisions to disclose inventions through the patent system; and, disclosure of inventions in patents exerts a stimulative effect on competitive R&D.

*Recommended Action*

First of all, the Patent and Trademark Office must be upgraded by being provided with more funds than presently allocated so that a proper job can be done both as to examination and technology transfer. If re-examination of patents is instituted, it should be mandatory that a litigant who raises a defense of invalidity of a patent based on newly found heretofore unconsidered prior art should first test the asser-

tion of invalidity in the Patent and Trademark Office, where the most expert opinion exists at a much reduced cost.

Secondly, the patent laws should be amended to recognize that reliability of patents is a keystone in the commitment of funds to carry out the commercialization of a patented invention, and that incontestability should be mandated after a period of time so as to result in absolute reliability, except in cases of fraud.

Thirdly, a viable technology transfer system shoud be implemented, based on expanded technology maintained in the Patent and Trademark Office with delivery thereof to small business enterprises from regional units in much the same way that the agricultural extension service operates. As part of such a program small business should be able to obtain a compulsory license through suitable proceedings in cases where uncommercialized patents block entry into new markets.

*Issue No. 21*—Technological innovation is the principal, and perhaps only, source of economic growth in advanced industrial societies, according to the noted economist Schumpeter. However, there must be an adequate supply of innovators, that is, people who have the requisite capability to generate and synthesize information relating to needs, opportunities, and knowledge in a form that can be empirically demonstrated

It should be realized that people are innovators. Institutions do not create; companies, big or small, do not create. Individuals create. Yet there does not seem to be a recognition of the need to teach innovation; nor alas, is proper recognition accorded creators, especially employed inventors. Ayn Rand, speaking through her protagonist in "The Fountainhead," said:

"Men have been taught that the highest virtue is not to achieve, but to give. Yet one cannot give that which has not been created. Creation comes before distribution, or there will be nothing to distribute. The need of the creator comes before the need of any possible beneficiary. Yet we are taught to admire the second-hander who dispenses gifts he has not produced above the man who made the gifts possible. We praise an act of charity; we shrug at an act of achievement."

*Recommended Action*

Attitudinal changes in favor of small business just now beginning must be encouraged, by providing for identification of individuls having innovation abilities, teaching innovation, and providing whatever follow-up support system necessary. There should also be established a program of insuring financial rewards to employed inventors and, very importantly, a program of tangible awards to small business innovators and to those contributing to the well being of small business.

CONCLUSION

Small business has taken very seriously President Carter's request that the climate for invention and innovation be investigated. Having identified the salient fact that invention and innovation were on a downward trend in the U.S., the National Small Business Association has undetaken a *policy analysis* of the institutions of government and the statutes and regulations that have a bearing on invention and innovation. Having accomplished a policy analysis, there must now follow a *policy synthesis*. The twenty-one recommendations presented herein for consideration when taken together and implemented are submitted to constitute that *policy synthesis* that will achieve increased invention and innovation overall and at the same time give a two-tier purview whereby small business is accorded special recognition due it for its past exemplary performance.

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BURROUGHS CORP.,
*Detroit, Mich., June 21, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, D.C.*

MY DEAR SENATOR STEVENSON: It is a pleasure to see the good progress you have made in encouraging industrial innovation, and I am especially pleased with the overviews you have cited in introducing your bill to promote U.S. technology. I have had some discussions on these matters with Alex Netchvolodov of Senator Danforth's staff, and I want to encourage you and your colleagues in your endeavors in this area, It is important, for our society, and for our way of life.

Your bill's proposal to encourage experiments to find out what will really stimulate innovation is particularly insightful. Each of us has his opinions about it, but the only way to find out is to try it. I hope you succeed.

I would like to add a few perspectives for you to evaluate in light of all else that you know. First, at least in the industry I know, computers, there are many more potentially good ideas to pursue than are pursuable. I suspect this is true in many other industries. The consequence is that corporations have enough great technology to do anything anybody is willing to pay for. In other words, engineering can design almost any new product that their business management asks them to design. Society today, measured in terms of new products designable, is not limited by technology. That in part is why, even in the rapid changing computer industry, we are spending more on new product development and less on creating new technology. Second, in my judgment, the best principle to follow to encourage technological innovation is to make it profitable. If companies large and small found it more profitable, they would apply their ingenuity and resources to that end. Why can't the Government allow us to do that?

Third, The creation of new technology just because its new is not helpful; it is a classically difficult research management problem to select those research projects which are most likely to achieve the ends desired. In your speech which accompanied the introduction of the bill, the prime motivation for the concern which prompted the bill appears to be the decline in productivity of the U.S. industrial community. Yet in the bill, itself, its purpose fails to mention productivity. Instead, the purpose is explained to be "to enhance technological innovation for the improvement of the economic, environmental, and social well-being". Of these improvements, only innovations affecting the economic area might also result in improved productivity indexes; improvements in environmental and social state would probably result in decreases in productivity measures. I suggest you rethink exactly what research objective you want this new office to pursue, and then provide the office with guidelines appropriate for selecting research projects that will maximize the expectation of achieving those stipulated objectives. As worded, any kind of new inventions are solicited, whether or not they increase productivity. That will lead to a lot of technological fun, but not necessarily great improvements toward what I thought you were aiming.

Sincerely yours,

R. R. JOHNSON,
*Vice President, Engineering.*

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HONEYWELL, INC.,
*Minneapolis, Minn., June 21, 1979*

Senator ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Thank you for the material on Senate Bill S. 1250 and your request for comment.

Anything that will strengthen the so-called University-Industry Connection merits consideration. As a member of advisory councils or visiting committees for the University of Washington, University of Minnesota and Carnegie Mellon Institute, I feel that the establishment of centers for industrial technology at our universities, if based on high standards of excellence, will do much to encourage technological innovation. Industry participation in this process, above and beyond current levels of sponsorship, will be very important in making the centers productive. To encourage industry to do more, tax incentives should be provided. I would urge your committee to sponsor appropriate legislation, as in a declining economy (because of impending energy shortages) the revitalization of innovation must be based on more than a government grant to the universities. Specifically, the language on page 8, lines 3 to 5, appears too vague; likewise the implications of paragraph (3) on page 9 require further clarification.

Sincerely,

THEODOR F. HUETER.

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THE CONTINENTAL GROUP, INC.,
*New York, N.Y., June 25, 1979.*

Hon. ADLAI E. STEVENSON,
*Committee on Commerce, Science, and Transportation,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: I'm sure you will find enthusiastic appreciation for the initiative that you have taken in sponsoring this bill. As you pursue this effort, may

I suggest that you might keep several critical points in mind in order to maintain perspective in a complicated situation:

(1) "Innovation" is basically a two-step process: the first step is the invention itself; the second step is the long tedious process of converting that invention into a product or process that has commercial value. Ninety percent of the cost, the time and the risk is involved in the second step.

(2) The first ("invention") step is alive and well; worldwide there has been—and continues to be—an explosion of technology which is generating thousands of new insights and product or process ideas.

(3) It is the second step that has been so impacted by regulatory restrictions, liability exposure, and particularly by inflation, that not even large companies can justify the exposure or "down-side risk" of mounting major new product development efforts.

(4) Incentives are ten times more effective in achieving a desired objective than are punitive measures, so please focus first on creating incentives for cooperation and joint effort between industry, universities and government.

(5) The other side of the coin is to eliminate some of the disincentives, perhaps by replacing them with incentives. A reward for being a corporate citizen might not be so bad . . .

I've attached a paper that appeared in a recent issue of "Management Review", an AMA publication. It expands on some of these and other concepts which are critical to the innovation process. And if I can be of help in any way, please let me know.

Sincerely,

D. BRUCE MERRIFIELD.

Attachment.

Reprinted from

The magazine for motivated managers

MANAGEMENT REVIEW

# How to select successful R&D projects

D. BRUCE MERRIFIELD

amacom A DIVISION OF AMERICAN MANAGEMENT ASSOCIATIONS

# How to select successful R&D projects

**Strategic analysis is vital to management and licensing of new product programs.**

*Commenting on society's accelerating change, Dr. George Berry, dean emeritus of Harvard Medical School, states that our era may one day be recognized as the second great divide in human history—the first being the emergence of civilization itself. Rapid change is uncomfortable and creates periods of crisis that have both elements of danger and opportunity. It is easy to focus on the risks or dangers rather than the opportunities. The challenge to leadership and to good management is one of simultaneously minimizing the risks and maximizing the opportunity. In the article below, the chief of technology at a leading U.S. corporation assesses the implications of this challenge in terms of research and development project selection and licensing.*

D. BRUCE MERRIFIELD

NINETY PERCENT of the knowledge we now have in the physical and biological sciences has been generated in just the last 30 years. All the Galileos, the Newtons, the Archimedes, and the Einsteins contributed but 10 percent of the total. And this knowledge will double again in the next seven or eight years.

In itself, this is a remarkable statistic, but it is only part of the picture. The more important understanding involves the ways in which this datum interacts within itself to create "surprise factors." This occurs when individuals combine discoveries from several disciplines and put them together in a new way to produce developments that were not at all anticipated in any of the original work.

Surprise-factor innovations occur constantly. The impact of microminiaturized electronics, for example, has made obsolete the slide rule and the once familiar mechanical-type calculators and has radically altered the watch industry. Fiber optics may revolutionize the communications industry, with secondary impacts on the fine paper business as electronic mail becomes commonplace. High-energy density batteries could soon revolutionize the automobile business.

Significant surprise-factor interventions will also likely develop from space technology, from demographic changes (a quarter of the earth's population is under five years of age and in countries that average six to eight children per family), and particularly from the world of biochemistry—where major interventions into the mechanisms of learning, memory, and other brain functions will combine with genetic engineering to extend productive life and health in unexpected ways.

Examples such as these—dozens might be cited—are intended only to underscore the fact that rapid change is an essential element of this period in history and that good management today is the "management of change." Effective strategic planning now is required for survival, and all available options including internal R&D, licensing, acquisition, and joint venture must be primary elements of such planning.

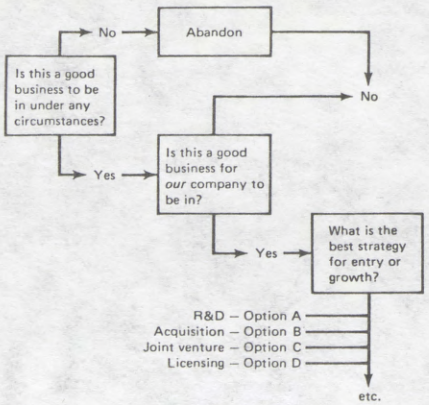
## Evaluating the better mouse trap

The statistics for R&D success are less than encouraging. Perhaps one of 20 programs that start out in the laboratory ever produces a positive cash flow, and the average time required from the idea stage to commercialization for major programs is seven to ten years. This is too long—the need may have disappeared or been satisfied in another way.

The constraint analysis I will describe here, however,

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**Figure 1**
**Basic Logic Sequence**




has produced eight out of ten successes and telescoped the time from two to four years. It is combined with staged management of the R&D process intended to further minimize the downside risk.

Constraint analysis is basically a logic sequence or decision tree that asks three questions (as illustrated in Figure 1): Is this a good business for anyone to be in? If yes, is this a good business for *us* to be in? If yes, what is the best method of entry?

Each of these questions has an expanded list of critical factors that have been selected through experience and can be expressed in the form of an index of merit ($I_m$), as shown in Figure 2.

It is important to determine, even before the first experiment is run, whether or not a new development could ever result in a commercially attractive product. (The shelves of research labs are cluttered with great mouse traps for which there have turned out to be no mice or for which the manufacturing, marketing, management, capital, and other requirements for commercialization were inadequate.)

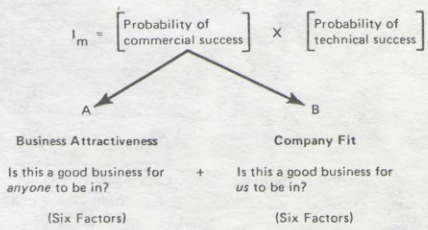
Figure 3 shows an expanded constraint analysis and "score card" for comparing program opportunities. Twelve factors are rated from 0 to 10, giving a maximum possible score of 120: 60 for "business attractiveness" and 60 for "company strengths." Over many years of experience, those projects with scores of 80 or above were successful in eight out of ten cases. The few that did fail did so because of unexpected regulatory interventions or from increased costs for raw materials because of the oil embargo, and occasionally a major program was discontinued because a parallel effort turned up a second-generation development that was superior to the first (all of which were, indeed, surprise factors). Below 70 points, the probability of success falls off rapidly. Following is a brief analysis of the 12 factors.

### Business attractiveness factors

1. *Sales/profit potential:* A rough guideline here might be that to achieve a rating of 10, the project should be able to generate, within five years of commercialization, an additional 10 percent in sales for the company or profit center toward which it is targeted, together with a 40 percent return on investment (ROI) before taxes on a discounted cash flow (DCF) basis. In other words, it should be sufficiently important to have a major impact on the company or on the targeted profit center, together with good ROI.

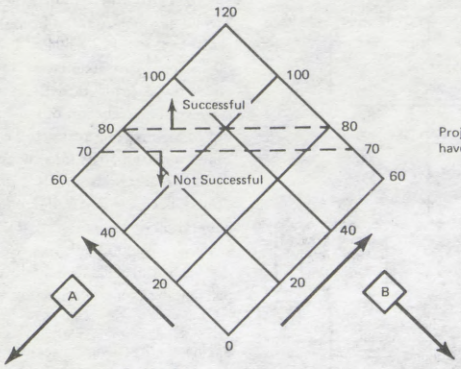
2. *Growth rate:* To achieve a score of 10, the expected growth (or penetration) rate should be at least 10 percent

**Figure 2**
**Index of Merit**




D. Bruce Merrifield, *Ph.D., is vice-president—technology of The Continental Group, Inc. He formerly was vice-president of technology at Hooker Chemical Company.*

**Figure 3**
**Score Card for Expanded Constraint Analysis**




Projects with less than 70 points have rarely been successful

| Business Attractiveness | Projects* I | II | III |
|---|---|---|---|
| 1. Sales/profit potential | | | |
| 2. Growth rate, %/year | | | |
| 3. Competitive situation: | | | |
| • Competitor reactivity | | | |
| • Activity index of technology | | | |
| • Patent position | | | |
| 4. Risk distribution (segments) | | | |
| 5. Opportunity to restructure an entire industry | | | |
| 6. Special political and social factors: | | | |
| • Antitrust | | | |
| • Ecology | | | |
| • Energy | | | |
| • Foreign exchange | | | |
| • Geography | | | |
| • Sovereign rights | | | |
| Totals | | | |

| B. Company Strengths** | Projects* I | II | III |
|---|---|---|---|
| 1. Capital requirements | | | |
| 2. Marketing capabilities | | | |
| 3. Manufacturing capabilities | | | |
| 4. Technology base | | | |
| 5. Raw material availability | | | |
| 6. Skills availibility: | | | |
| • Champion | | | |
| • Technical, legal, financial, etc. | | | |
| Totals | | | |

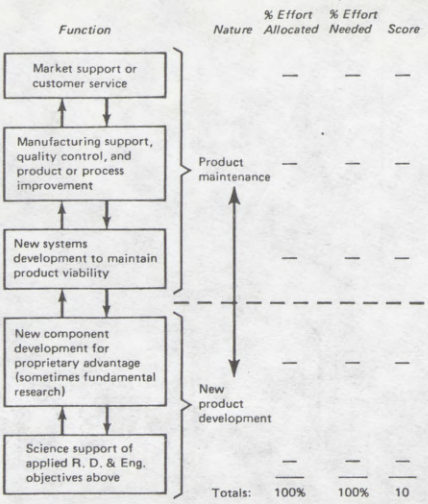
*Rate each factor on a scale of 1 to 10

**Company strengths (Fit factors)

per year in unit volume or in sales after adjustment for inflation. (A rising tide raises all boats.)

3. *Competitor analysis:* Key considerations here are (a) what measures can or will the competition take when their market share is threatened by the new development, (b) how strong is the patent that will bar competition in at least the early stages of commercialization, and (c) what is the "activity index" for this area of technology—that is, what is the possibility that this new development will soon be superseded by even better products and therefore have a very short life span. Assign a maximum of 4 points to (a) and 3 points each to (b) and (c) for a total of ten.

**Figure 4**
**Strength of the Technology Base**




4. *Risk distribution:* Are all the eggs in one basket or does this development have at *least* four or five potential applications of significant size—either from a marketing or from a manufacturing point of view—so that if an able competitor develops a superior product in one of these areas, there will be three or four left. This is a form of insulation from the surprise factor that can make almost any product line obsolete in five to ten years. Assign 10 points if there are at least four or five significant segments of the market to which this technology can be addressed and fewer points if there are less.

5. *Industry restructure opportunity:* An ideal situation to illustrate this important factor would be one where a significant technical development with strong patent protection has been made in an otherwise technically stagnant industry that is also badly fragmented among a number of small competitors but has an attractive total business potential. An opportunity to "restructure" such an industry is particularly attractive because the need is already established and penetration could be very rapid, particularly with the selective acquisition of one or two of the small competitors who may have marketing or manufacturing capabilities upon which to build. Assign ten points for a major restructuring opportunity and fewer for lesser degrees of such opportunity.

6. *Special factors:* Possible political, social, and economic surprise interventions are important to consider. Here are included regulatory agencies (FDA, EPA, OSHA, and so forth), antitrust action, sovereign rights, foreign currency exchange fluctuations, federal funding or subsidy considerations, and the possibility of further energy dislocations. Geographical advantages or disadvantages affecting freight and distribution costs need to be weighed. Assign 5 points if there are *neither* negative or positive factors. Assign less if there are negative factors and more if there are subsidies available.

### Company strength factors

1. *Capital needs vs availability:* An opportunity that is not capital intensive carries a lower risk, particularly for a company with limited cash flow, but such an opportunity also invites competition. On the other hand, for a company with a strong cash flow, a capital intensive situation presents an entry barrier to others, which limits competition to some degree. Assign a 10 rating for a strong cash flow in a capital intensive situation and fewer points in a situation less capital intensive. Where a company has a weak cash flow, assign a maximum of 5 points for a low capital intensive situation, with points decreasing as capital intensity increases.

2. *In-house marketing capability:* If a new development fits directly into a strong in-house marketing, distribution, and technical service capability, the time required for commercialization will be significantly shortened and the probability of success enhanced. However, the strength of the internal marketing capability should be evaluated relative to the competition. Building a new sophisticated marketing capability can add two or three years to the commercialization process, during which the "need" may disappear or competitors find different solutions. Assign 10 points for a strong in-house existing capability and fewer points for a weaker situation.

3. *In-house manufacturing capability:* If facilities exist in-house where prototype production can begin and early (or interim) commercial production be accomplished, then time to reach commercialization again will be shortened, and capital expenditures may be delayed—at least until the probability of commercial success is well established and risks have been substantially reduced. Assign 10 points for an existing full-scale manufacturing capability requiring little modification to make the new product. Assign 5 points for an "interim" manufacturing capability.

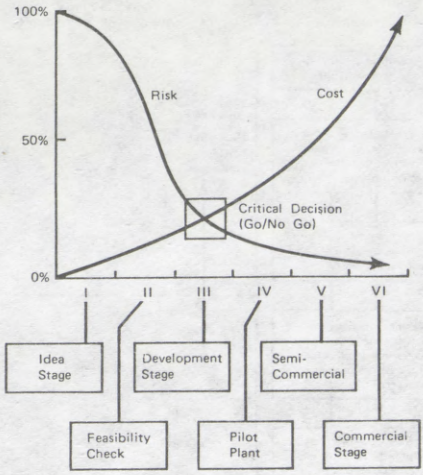
4. *Strength of the technology base:* Proprietary technology rests on patent protection and accumulated know-how derived from technical service to sales; process and engineering/design experience; formulation, assembly, and packaging expertise; and the ability to develop unique components and to provide basic scientific support for them. A new development that builds on an established base of this sort will have a significant advantage over competitive systems that are not so strongly based. Ability to react quickly to unexpected innovations or to overtake established, but stagnant, technology is also enhanced by a strong technology base.

Figure 4 assesses the strength of the technology base in functional terms. There are five functions: If the percentage of effort allocated approximates the percentage of effort needed, score 2 for that function. If there is a significant difference between the effort allocated and the effort needed, score 0 or 1. The sum of the scores of the five functions determines the point value of the technology base (maximum 10). The amount of effort ideally allocated to each level will depend on the position of the business in the maturity cycle. An embryonic business will usually have both a greater total effort and a greater percentage allocated to the bottom two categories on the chart (new product development). A declining business tends to allocate most of its total effort to the top two categories (which fall under product maintenance).

5. *Raw materials availability:* An assured supply of basic components or raw materials is an essential element that determines whether a company can profitably commercialize a new product. A backward integrated raw material position holds the lowest risk. Having several suppliers, working on long-term contracts, and using "politically insensitive" starting materials may become increasingly important to commercial success—as might be inferred from the 1974 oil embargo. Score according to raw materials accessibility, with a maximum of 10 points.

6. *Management and other skills:* In-house availability of critical management, legal, and financial skills is essential to effective commercialization. Most important is the availability of a manager who believes deeply in the project and persistently pushes it to completion. His or her skill in managing the interfaces between operations is critical. More potentially successful programs have probably failed for lack of a champion than for any other reason. Availability of skills will vary for each project and needs to be analyzed carefully in terms of functions to be performed. For top-notch talent, 10 points.

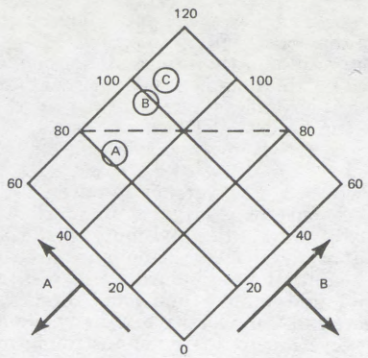
**Figure 5**
**Critical Decision Point in R&D Pipeline**




Use of this constraint analysis allows direct comparison of dissimilar opportunities vying for (always) limited resources. Moreover, the "stochastic" interaction of these variables with each other provides a statistical probability of success for those over a minimum (80 point total) score.

The analysis should be run at each stage of development in the R&D pipeline, starting at the idea stage, as shown in Figure 5. A critical decision point occurs in the late development stage where costs begin to escalate rapidly. At this point, the probability of both commercial *and* technical success should be high in order to proceed. Also, at each decision point in the pipeline, it is helpful to simulate the financial factors involved and to chart the sensitivities of the projected ROI/DCF to variations in capital, materials, production throughput, labor, utilities, and price structure. This simulation targets the priorities for continued technical development.

**Figure 6**
**How Constraint Analysis Led to Licensing Strategy**




A = Company (X) Alone

B = Company (X) + Company (Y)

C = Company (X) + Company (Y) + Company (Z)

| A. Business value factors | Score |
|---|---|
| 1. Sales/profit potential | 10 |
| 2. Growth rate | 10 |
| 3. Competitor analysis | 8 |
| 4. Risk distribution | 6 |
| 5. Industry restructure | 8 |
| 6. Ecology, etc. | 7 |
| Total | 49 |

| B. Company fit or strength factors | A | B | C |
|---|---|---|---|
| 1. Capital needs | [0]* | 10 | 10 |
| 2. Marketing | [0] | [2] | 8 |
| 3. Manufacturing | [3] | [5] | 7 |
| 4. Technology base | [5] | 6 | 6 |
| 5. Raw materials | 10 | 10 | 10 |
| 6. Management | [4] | 6 | 8 |
| Totals | 22 | 39 | 49 |

*Boxes indicate weaknesses requiring additional strength

Finally, weaknesses that show up in the constraint analysis (Figure 3) point up areas where selective acquisitions, joint ventures, or licensing strategies may either "rescue" an otherwise attractive program or offer a low-risk method of entry into a new business area.

An example of this latter strategy is shown in Figure 6, where Company X developed a breakthrough in technology with exceptional business potential that could restructure two or three major industries—each with sales of more than $300 million and all of which were mature and badly fragmented among small competitors.

Rapid penetration based on a solid proprietary (patent protected) position was envisioned. However, Company X, recognizing its weaknesses in capital availability and both marketing and manufacturing capabilities, licensed the technology to Company Y, which brought strong cash flow to the picture, together with some technical and management strengths, but little in the way of marketing and manufacturing capabilities. A third company, Z, was brought into the picture as an exclusive sub-licensee in one segment of the business on a very attractive basis for both Y and Z. The probability of commercial success was substantially enhanced by this strategy, which has worked out well.

An alternative option to "go it alone" might also have been successful but was judged to have a greater downside risk and to require a longer time for commercialization. •

MERCK & CO., INC.,
*Rahway, N.J., June 25, 1979.*

Senator ADLAI E. STEVENSON,
*Committee on Commerce, Science, and Transportation, Senate Office Building, U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Thank you for your inquiry of June 8 concerning S. 1250. I am pleased to have the opportunity to respond.

I strongly endorse the objectives of the proposed National Technology Innovation Act of 1979. Having served on the Commerce Department's recent Domestic Policy Review of Industrial Innovation and as vice-chairman of the Federal Science and Technology Committee of the Industrial Research Institute, I am acutely aware of the problems which face our nation in its competition for international technological leadership.

The specific means by which S. 1250 intends to advance these objectives are not unreasonable when seen as part of a larger framework which will be required. Improvement of the ability of universities and industry to collaborate in generating new technological ideas is a key element in enhancing our innovative capability. Although I would not be against the mechanisms proposed in S. 1250, the means of accomplishing this which I find simpler and more direct is a program in which industrial grants for research in a university are matched on a sliding scale by tax credits from the federal government to the industrial grantor. A more detailed description is enclosed.

Creation of generic technology broadly useful to certain industrial sectors is also a goal which I endorse. The great success of the National Institutes of Health in supporting basic research in the biomedical area, research leading eventually to new drugs and vaccines, is a good precedent. With regard to the steps proposed in S. 1250, specific concerns which I have would be:

1. How to maintain the freshness of approach and flow of new ideas for any such center. A research institution must constantly combat institutionalization, bureaucracy, and senescence. The National Institutes of Health and, of course, universities arrange for a constant turnover for a fraction of their staffs, and this should be a feature of the proposed centers.

2. A maximum amount of industrial and academic input and minimal involvement of governmental administration is essential in my view. It is extremely difficult for governmental granting agencies in their zealous pursuit of accountability to prevent an escalating paper burden for research grants—a burden which finally stifles the very innovation and creativity which the original program had intended to stimulate.

3. As is recognized in your remarks in the Congressional Record, sectoral differences in American industry are of paramount importance. It is not possible to help an industry which, for example, has become capital-intensive and which has lost its innovative spark in the same way as an industry which has traditionally financed a high level of R&D and maintained a strong and competitive technological position.

A specific proposal which is closely related to the idea of centers and which, like the proposal to strengthen industrial/academic interactions, arose from the Domestic Policy Review Committee is also enclosed. It has many attractive features from the industrial viewpoint.

Finally, I take this opportunity to suggest for your consideration a national prize for innovation (Annual Presidential Awards for Technological Innovation); a proposed draft is enclosed. I have discussed the idea in a preliminary way with Mr. Frank Wolek of the Commerce Department and with Mr. Phil Smith of the OSTP; and, although at a very preliminary stage, I believe they have found merit in the concept.

Sincerely,

LEWIS H. SARETT.

Enclosures.

I. UNIVERSITY-INDUSTRY RELATIONS

University research is a $4 billion resource and represents a significant fraction of the total Research and Development commitment of the U.S. and the major portion of the Research part of it. Seventy percent of university research is funded by the Federal government but only 3 percent by the industrial community compared to 55 percent and 7.5 percent respectively in 1953. The panel senses that there has been an ever widening gap between the university and industrial communities and, as a result, this key national source of new technical knowledge is not being adequately tapped for its innovative potential by the private sector—the sector with a major

responsibility for innovation in the U.S. One of the factors evidencing this diminution of the influence of university research on innovation in the private sector is the paucity in today's environment of new innovative businesses such as populated the Route 128 and Palo Alto communities in the fifties and sixties. The growth and success of these enterprises was importantly influenced by the university communities in their respective geographical locations.

The panel therefore recommends that it should be a goal of Federal policy to support a substantial increase in the level of coupling of university research with the industrial community without compromising the fundamental tenet that university research be publishable and freely available.

"A parallel opportunity exists for the coupling of Federal laboratory research with the industrial sector. The unclassified results from the $6 billion Federal laboratory research programs are not being adequately tapped for their innovation potential by the private sector."

Policies to achieve this goal can be expected to:

(1) Increase the utilization of the results of university research by the industrial community thus stimulating the rate of industrial innovation.

(2) Increase the societal relevance of university research by broadening the exposure of its research personnel to the pluralism of society's needs as evidenced through industrial community as well as by the Federal R&D funding agencies.

In considering new initiatives to achieve this policy goal, the panel suggests that the Federal government carefully consider the risks inherent in any major shifts in the basic motivations of the two principal institutions involved—the universities and the industrial community. It is hoped that the resulting increase in university/industry coupling will be viewed by industry for what it could become; a significant opportunity to invest people and material resources in an opportunity that in total will be of significant benefit to employees, customers, shareholders, and society—an opportunity that can compete successfully for resources with other investment opportunities available to the industrial community.

It is also hoped that the resulting increase in university/industry coupling will be viewed by the university community for what it could become; a significant opportunity to broaden the pluralism of the university community's interactions, thus improving its capability to meet society's education and research needs.

For these reasons, the panel recommends that the Federal initiatives be designed primarily to simulate closer coupling of the universities and industry leading overtime to a major increase in the funding of university project by the industrial community.

Policies to achieve this goal should be designed in way which will assure the following:

(1) That the final control of, and responsibility for, research undertaken in universities remains clearly in the hands of university researchers. (Interaction with, and support from, industry should provide perspective and insight, not control.) The emphasis should be on fundamental research—especially the longer term fundamental research that frequently cannot be justified in the research program of a single company—and generic technologies widely applicable beyond the specific interests of a single company or industry.

(2) That universities retain any patent and publication rights arising from the research.

(3) That small entrepreneurial companies have a substantial opportunity to participate in and benefit from the closer coupling.

Some policies cannot be expected to succeed without enthusiastic cooperation from both the academic and industrial sectors. However, the following Federal Policy options can be expected to accelerate the process.

(1) Direct Federal support to university researchers for the purpose of strengthening the dissemination of their research findings to industry. (Such grants could be an "add-on" to grants for university research being funded by Federal agencies under existing programs or could be made independently.) Some Federal R&D grants already contain such provisions.

(2) Direct Federal funding of universities for research aimed at better understanding and defining the needs of the industrial community.

(3) Direct Federal support to universities for the purpose of organizing industrial consortia with the objective of providing ongoing dialolgue and research grants from the industrial community.

(4) Direct Federal funding of matching grants to stimulate the university desire to carry out industry funded research whether originated by the university itself or suggested by industry. The size of the matching grants would be derived on a formula basis from the size of the industry funding and would be used for research

projects selected by the university in the general area of technical interest represented by the industrially funded project.

The matching funds should reflect the size of the company funding the research. Small company projects would stimulate larger grants matching funds.

(5) Initial incentives to industry, to encourage their involvement in closer coupling with the universities. They are also intended to forestall any tendency to reduce internal industrial R&D. The incentives could be in the form of special tax credits or grants to cover a portion of the industry funds spent in universities (industry funds spent for contract research, where industry retains proprietary rights, would not qualify for these incentives). The need for these incentives is expected to diminish once the value of the program becomes fully apparent to industry.

It is believed that encouragement and leadership from the Federal government could play a key role in ensuring both university and industry commitment to this program. The President could usefully charge both industry and the universities to take a more proactive role in their interactions with each other in the research area.

"Specific mechanisms for encouragement of increased interactions involving Federal Laboratories were not discussed by the panel. However, it was noted that both NASA and particularly the Department of Agriculture have, with varying degrees of success, conducted vigorous programs to help industry utilize technology developed in their laboratories. A study of these efforts should provide the basis for the development of the necessary mechanisms."

Long term, these policies can be expected to increase substantially the effectiveness of the research, development, and innovation in both the private and public sectors.

Additional benefits to be derived from such a program are:

To provide "seed money" for fundamental research studies of a longer range nature that cannot be included in most industrial research programs.

To expand the technical exchange and understanding between people in universities and people in industry in areas beyond a specific project, through the personal interaction of those involved.

To provide more balance and a broader base toward the industrial needs of the future both in education and technology.

To involve minimal governmental overheat expense in the execution of this program.

To assure results significant to industry, as no company would contribute their money and time to projects of no value. (Note: This does not mean that every project will result in an industrial product or process. Negative answers preventing going down unsuccessful paths are frequently just as important.)

To permit individual project decisions to be made by those directly involved.

To provide an increased base of university publications and patents of potential interest to many industries.

To provide rapid response to proposals which will aid in the stability of university planning.

### III. SUPPORT OF R&D ON GENERIC TECHNOLOGY

1. Direct federal support, together with industry, of research, development, and dissemination to U.S. industry of new technology, generic to process or product innovation in wide spectra of industries, should be strengthened and recognized as federal policy. The mechanism for accomplishing this should have the following features:

(a) Development of a coordinated network of Cooperative Technology Centers (centers of excellence) in various fields of generic technology, distributed throughout the U.S. system of universities and colleges.

(b) Conduct, at each of these Centers, of research and development of new generic technology in the field of excellence—technology needed by industry to accomplish process or product innovation.

(c) Dissemination to, and assistance in utilization by, U.S. industry of such technology, wherever it originates in the world, including economic studies to evaluate potential return on investment from implementation of the generic technology by industry.

(d) Planning and policy-type guidance of the research, development and dissemination programs of each Center by an associated Working Group made up primarily of representatives from interested industry, but with representatives of the university or college and of the Federal Government also participating, and making use of the neutral ground of appropriate engineering societies for organizing and serving as secretariats for these Groups.

(e) Planning, policy-type guidance and stimulation of the overall Cooperative Technology Centers activity, on a national scale, by a Cooperative Technology Council, under the aegis of the Secretary of Commerce, and again made up primarily of representatives from industry, but with representatives of universities, colleges and the Federal Government also participating, and making use of the neutral ground of the Engineers Joint Council for organizing and serving as a secretariat for this Council.

(f) Directed emphasis and priority to be given, in the local and national planning, guidance and stimulation, to research, development, and dissemination activities particularly pertinent to the needs of small companies and trade impacted, technology impacted, regulation impacted, resource impacted, or disaggregated industries.

(g) Funding for the Centers, and of the overall program, to come jointly from industry and the Federal Government. In particular, the federal funding should be used:

(1) To initiate the overall program;

(2) As seed money for early, high risk research and development of new, advanced generic technology;

(3) To help attract industry funding into such research and development programs as early and as fully as possible;

(4) Continually to assist the Centers in their process of dissemination and transfer to industry of new generic technology, wherever it originates in the world. Use of the federal procurement process to stimulate or accelerate such transfer should be included in appropriate cases.

2. Since the Cooperative Technology Centers activity must start small and gradually evolve to cover all fields of generic technology, the field of manufacturing technology, as the area having the greatest potential for economic and social benefit to that nation, is recommended as a particularly appropriate field in which to initiate such activity. Recommended as an especially appropriate initial focus in this field is the still incipient generic technology of computer integrated manufacturing—harnessing the computer to optimize and automate manufacturing fully from product design through final inspection. This technology is one in which the U.S. is rapidly falling behind the rest of the world, yet one having by far the greatest potential for economic and social benefit, for increasing employment, and for enhancing the international competitiveness of U.S. industry, if properly researched, developed and then utilized. Cooperative Technology Centers (centers of excellence) should be established in this field, developing R&D and dissemination programs for such areas as computer aided design (computer graphics), computer optimized production planning, computer optimized production control, computer automated manufacturing equipment and systems, computer controlled in-process inspection and quality assurance, computer automated assembly and robotics.

Here the appropriate engineering society for organizing and serving as secretariat for the Working Groups associated with these Centers would be the Society of Manufacturing Engineers. Appropriate first year federal funding would be $15 million.

Appropriate future fields of activity, as the program develops, would be the social sciences and the life sciences, particularly as related to research, development and utilization in industry of new knowledge concerning methodology for capitalizing on the potentialities of the technology of computer integrated manufacturing for increasing quality of working life, health and safety in industry.

*Rationale*

Highly effective stimulation of industrial innovation can be accomplished by direct support, by government, of research and development of appropriate, new, generic technology—technology which enables industry to move in new directions in processes and products, but is not, a priori, directed at development of specific, proprietary-type new processes or products. This is so because such new technology, generic to industrial activities, and in the public domain, can then be drawn on by industry as a whole to innovate new, specific, proprietary processes and products.

Accomplishing such stimulation by developing a coordinated network of Cooperative Technology Centers (centers of excellence) in various fields of generic technology, and locating these at universities and colleges, in the manner described in the above recommendation, provides a mechanism having maximum potential for facilitation of innovation in industry. The following factors at work in such a mechanism are particularly significant to the potential:

1. A strong coupling and working relationship between industry, universities and government. This comes about first because of the interaction and coupling of the powerful resources of all three that must take place in the planning, guiding and stimulation of the generic research and development to be done in support of

innovation in industry. Secondly, it comes about because of the joint roles that governments and university resources must play in assisting the dissemination or utilization of generic advanced technology (wherever it originates in the world) into industry.

2. An increase in the quantity and quality of engineering graduates available to industry. This comes about, first, because significant support of research in a given field in universities automatically attracts the most capable faculty to that field, who in turn attract more and better students to that field of study. Secondly, the fact that the research and development being supported must have direct relevance to promoting innovation of advanced technology in industry (i.e., be focused on real industrial problems and needs) means that students in that field of study, by virtue of that orientation of their faculty, will receive an education more tuned to the real needs and problems of industry.

3. The provision of neutral ground for government, university, industry cooperation. Government, university and industry can work together most effectively and freely if all three ar on neutral ground. Fortunately, a highly capable and knowledgeable neutral ground is ready made—the professional technical society. This mechanism is used very effectively in other countries, such as Japan, for just this purpose. Working groups made up of appropriate representatives from industry, universities and government provide specific planning and policy type guidance of each significant area of university research and development of generic technology to be undertaken, as well as of the transfer of the results of that to industry.

A case history demonstrating the major facilitation of innovation in industry which can come about when a university center of excellence, government and industry are coupled is found in the origination of the generic technology of numerical control of machine tools—a technology which resulted in cost reduction in the metalworking machining operation of better than two to one, compared to conventional machines. The history of this cooperative innovation is described in the paper "Crucial Decisions During the Evolution of Numerical Control" by Professor J. Frances Reintjes of M.I.T., presented at the 1977 Annual Meeting of the Society for the History of Technology.

The rationale for the selection of the generic technology of manufacturing technology, and in particular of the still-incipient technology of computer integrated manufacturing, as a particularly appropriate initial activity for this program derives from factual information developed by the Society of Manufacturing Engineers. This is presented in their 1978 Position Paper titled "The National Role and Importance of Manufacturing Engineering and Advanced Manufacturing Technology." This paper points out the fact that manufacturing constitutes over two-thirds of the total wealth-producing activity in the United States.

Thus, reduction in the cost of manufacturing, as the major wealth-producing activity of this country, can have a major salutary effect on the economic health and well-being of the nation, as well as on its competitiveness in world markets. Further, since the generation and support of new jobs in the economy rises primarily from reduction of the cost of wealth production, reduction of the cost of manufacturing can also be powerfully beneficial toward attainment and maintenance of full employment in the economy.

By far the most potent agent for reduction of the cost of manufacturing is new or improved manufacturing technology. Such new or improved technology derives directly and primarily from manufacturing research and development. Thus, support of research and development of advanced manufacturing technology by a nation has maximum potential for economic and social benefit to that nation.

The particular area of manufacturing technology being recognized world-wide as having by far the greatest potential for reduction of the cost of manufacturing (and thus being most actively pursued by many industrialized nations today in their national programs of R&D and industrial implementation of generic technology) is the still incipient generic technology of computer integrated manufacturing—harnessing the computer to optimize and automate manufacturing fully from product design through final inspection. However, realization of this potential requires careful integrated planning, policy-type guidance and stimulation of research, development and assistance to industry in its utilization, such as offered by the Cooperative Technology Centers program—a fact well-recognized in the programs of a number of other nations.

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### Proposal for Annual Presidential Awards for Technological Innovation

The Annual Presidential Awards for Technological Innovation will be given in recognition of outstanding industrial technological innovation. Through this

medium, the President of the United States will lend his prestige to the contributions of up to six companies annually for success in inventing, developing and marketing technological innovations. The existence of these awards will thus provide direct and explicit encouragement to U.S. industry on the part of the Executive Branch as well as the implicit endorsement of other branches of government.

Awards will be made in six areas: transportation, communication, health, agriculture and food, and natural resources (including energy), all other.

Since the path to innovation is a lengthy one and depends upon many individuals working in harmony, the awards will be to companies rather than to individuals.

The Department of Commerce will be delegated the responsibility for presenting the President with a proposed list of nominees each year.

The criteria for selection of outstanding innovations will include technical excellence and commercial impact including export and licensing potential.

Entries will be submitted by contending companies. Those eligible will consist of U.S. based corporations. The award will consist of a scroll and a plaque.

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GEORGIA INSTITUTE OF TECHNOLOGY,
SCHOOL OF INDUSTRIAL AND SYSTEMS ENGINEERING,
*Atlanta, Ga., June 26, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology and Space,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Thank you for the invitation to comment on your proposed National Technology Innovation Act of 1979 (Senate bill 1250). I believe it is a very well-conceived effort to address one of the most critical issues facing our nation today and, more importantly, in the future. I find the thrust of the effort excellent. I believe the proposed Centers offer great potential to contribute practical short-term gains and, more importantly, long-term payoffs. The notion of encouraging policy experiments is outstanding.

I would like to raise two clarification questions, then offer one substantive suggestion.

Regarding the Centers, what is their proposed duration? I take it that this is to be left to the Director's discretion. I would urge that the Center grants be of sufficient duration to allow job security desirable in attracting superior personnel to the venture. However, I would also urge limited expectations to allow the Director flexibility to cancel or reform some Centers. Initial grants of about four years with continued funding an open issue could serve these ends.

Regarding Section 7 grants and cooperative agreements, what is their relation to the Section 6 Centers? Are grants to be solely to Centers? to be determined by the Centers? to be processed through Centers? or to be independent of the Centers?

Turning to my substantive concern, I would urge that the Office be conceived as entrepreneurial. The atmosphere ought to be one of action, I feel. To transmit this flavor, I suggest that a title such as the Office of Industrial Innovation would offer more of a sense of mission. Some specific suggestions to convey a sense of action include:

Make the tone of the duties of the Office listed in Section 5 more action-oriented. They now suggest "studying and reporting" rather than "doing." The Office ought to be promoting innovation. (Certainly, study and assessment belong as basic duties—but don't stop there or make them pass the baton to other agencies.)

I suggest the intent of the Act include small cores of Office personnel devoted to specific tasks. For instance, a small unit might work on identifying foreign technologies with potential U.S. applications. Another unit might actively promote use of such technology through ongoing field work with industrial organizations. Such core staff should actively "market" the Office, cooperation with it and the Centers, and its specific innovations for development.

I believe a critical link to be involvement of industry in the effort, as the Act implies. I suggest strong industry voice in the formulation of the Office; the Centers, and the grant program. I would go so far as to suggest you establish an ad hoc advisory panel now to generate interest in and eventual support for the Office.

A Council of trade associations and others (e.g., professional societies such as the Institute of Electrical and Electronics Engineers, specific firms) should be set up to foster innovation. This would be a more action-oriented organizational structure than a review panel. I conceive of such a "Council" first as a voice in formulating Office and industry priorities. I feel such a group working with the Office could help identify problems and classify them on such grounds as seriousness, timing, and responsibility for solving (single firms, single industry, cross-industry, or industry-

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government). Furthermore, such a group could be an active dissemination mechanism for Office staff, Center, grantee, and cooperating industry developed information.

Lastly, I suggest that industrial commitment be cemented by requiring monetary contributions to be on the Council. Individual companies and trade groups ought contribute support for special Office ventures (e.g., supplemental grants to pursue short or long term issues, industrial fellowships to spend a year or two working for the Office or a Center). I believe such contributions would serve several purposes, including "stretching" taxpayer monies. But chiefly, the intent is to build industrial commitment to the Office's efforts.

Thank you again for the chance to comment and I wish you well in the effort to develop and secure passage of this important legislation.

If you would like to pursue any of the ideas mentioned or if there is anything further I could do to be of assistance, please let me know.

Sincerely,

ALAN L. PORTER, Ph. D.,
*Associate Professor.*

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## "AN ANALYSIS OF THE NATIONAL TECHNOLOGY INNOVATION ACT OF 1979" [1]

### INTRODUCTION

There is strong evidence that the rate of technological innovation is declining in the United States. It is clear that technological innovation is part of the solution to many of the economic, social and environmental problems we face today. For example, the sharp pains of the current energy crises can be reduced through conservation and shifts in consumption patterns, but the ultimate solution to this problem hinges on the development of new and improved technologies for utilizing sources of energy.

Increasing the rate of technological or industrial innovation is a national problem; and the Congress of the United States is well-advised to consider legislation to promote industrial innovation in order to achieve national, economic, environmental, and social goals.

### AN OVERVIEW OF THE NATIONAL TECHNOLOGY INNOVATION ACT (S. 1250)

The intent of the National Technology Innovation Act is valid. As noted in Section 2:

"Technology and industrial innovation offer the potential for contributions to an improved standard of living, increased public and private sector productivity, creation of new industries and employment opportunities, improved public services, and enhanced competitiveness of United States products in world markets."

Thus, it is clear that Congress should take action, but it is unclear what action Congress should take. As further stated in Section 2:

"Government antitrust, economic, foreign, patent, procurement, regulator, research and development, and tax policies and programs have significant impacts upon industrial innovation and development of technology, but there is insufficient knowledge of their effects in particular sectors of the economy."

In analyzing the National Technology Innovation Act, the purpose of this legislation should be firmly established. Section 3 appropriately identifies the purpose as being "* * * to enhance technological innovation directed toward the improvement of the economic, environmental and social well-being of United States citizens." The purpose is not to develop technology for technologies' sake or to engage in incremental improvement. Furthermore, it is not intended to benefit large or small industry or universities. Its purpose is to enhance the well-being of the citizens of the United States. Thus, it is people who are the intended beneficiaries—not industries or technologies. The partners in this legislative venture—industry, institutions, and government—need to keep this in mind.

Given the nature of the innovation process and our lack of an adequate understanding of that process, the general nature of S. 1250 is, in a sense, appropriate. Flexibility is essential if the program is to fit the diverse and changing needs of the environment for which and in which it is intended to function.

However, S. 1250 may be too general in the direction it provides. If the intent is, in fact, to stimulate technological innovation through unaffiliated technological inventors, new venture start-ups, and technological smaller enterprises, S. 1250 in

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[1] Prepared by: Gerald G. Udell, Director, Innovation Center, University of Oregon, Eugene, Oreg. 97403, and Pastor, Faith Center Church, 1410 W. 13th, Eugene, Oreg. 97403.

its current form is likely to fall short of that mark. As it is currently structured, the authorized incentives are likely to drift in the direction of: (1) An emphasis on technology rather than innovation; (2) a corporate-oriented and involvement; and perhaps (3) a more basic rather than applied approach to research.

If the intent is that the program should address the problems of getting relevant new technologies into the marketplace as well as generating those technologies and involving technological smaller enterprises and unaffiliated inventors, this intent should be so indicated. In the absence of strong program leadership, it is likely that involved universities will succumb to their natural inclinations and gravitate toward basic research and a partnership with corporations.

Basic research is the cornerstone of technological innovation, and corporations and institutions are obvious major partners in industrial innovaion. However, the important of technological smaller enterprises and unaffiliated technological inventors should not be ignored. Similarly, the fact that industrial innovation is not just a matter of technological skill, but of business skill as well.

SECTION-BY-SECTION ANALYSIS AND RECOMMENDATIONS

Section 2 is, for the most part, appropriate. However, it fails to recognize the importance contributions of non-corporate/non-institutional inventors and innovators. In light of the tendency to overlook this source of innovation, it may be appropriate to recognize this (and other) source(s) of innovation.

Section 3, as noted earlier, appropriately establishes the purpose of this legislation to enhance "* * * the well-being of United States citizens." Technological innovation is correctly identified as the means to an end.

Section 5 is worthy of comment in several areas:

(a) There are several federal agencies which have an interest in technological innovation. The Department of Commerce appears to be the most appropriate host agency for a technology-oriented industrial innovation. However, the title of the "Office" ought to clearly reflect its mission. The words "Industrial Technology" are somewhat unclear in this respect, i.e., the title should include the word "Innovation" to clarify the mission of this office.

(b) The importance of the Office is appropriately underlined by this subsection. That is, Presidential appointment of the Director, by and with the advice and consent of the Senate, provides proper recognition of the Office and its mission. The Senate, in approving the appointment, should look closely at the qualifications of the individual. He or she should be technically qualified with a thorough understanding of the innovation process and existing incentives to individual innovation. The Director should also have broad experiences in dealing with universities, and possess an intimate knowledge of government.

(c) The duties outlined herein are necessary in expanding our knowledge about the industrial innovation process, and those factors upon which it impacts and their impact upon it. It is appropriate to focus this work.

(d) Three years is an appropriate period of time in which some results should be possible, some tentative conclusions drawn, and recommendations made.

Section 6 authorizes the establishment of Centers for Industrial Technology. Although 6, subsection (a) properly identifies the objective of the Centers, their title, i.e., Centers for Industrial Technology, is unclear. The title "Centers for Industrial Innovation" reflects the intended nature of these Centers. However, the methodology outlined in subsection 6(a) for obtaining this objective may fall short of this mark. Items (1)–(7) are appropriate strategies for stimulating corporate innovation. The benefits to smaller technological enterprises and unaffiliated technological inventors and innovators are doubtful. Corporations may have the non-technical and financial resources necessary to carry new technologies through the latter stages of the innovation process. This may not be the case with smaller enterprises, and usually is not the case with unaffiliated inventors and innovators.

Some assistance may be available through other programs, such as SBA's Small Business Development Centers and EDA's University Centers. However, neither of these programs have technological innovation as their primary focus; and it is unlikely that these centers will have the necessary technological expertise available to provide the needed incentives to technologically oriented smaller enterprises and unaffiliated inventors and innovators. Accordingly, subsections (a) (4) and (5) should be changed:

(4) should be changed to read, the education and training of individuals in industrial innovation and entrepreneurship;

(5) the improvement of mechanisms in the dissemination of scientific, engineering, managerial and technical information from university to industry;

and the following additions are suggested:

(7) the provisions of those management and technical incentives necessary to stimulate industrial innovation among technologically-oriented smaller enterprises and unaffiliated inventors and innovators; and

(8) cooperation with other agencies and programs with an interest in and impact upon industrial innovation.

In addition, the title of the Centers should be changed to "Centers for Industrial Innovation" or "Centers for Industrial Technology and Innovation".

Section 6, subsection (d) helps to bring the activities of the Center into sharper focus. However, the managerial aspects of industrial innovation are not properly recognized. This can be corrected by changing item (3) to: management and technological assistance and advisory services to technologically-oriented industry, smaller enterprises, inventors and entrepreneurs.

The requirements for establishing a Center outlined in 6, subsection (c) are appropriate. Not all universities are suitable as host institutions. Some lack the necessary interdisciplinary resources. Still others lack a suitable institutional environment, or will not be able to develop the necessary internal or external financial support. In addition, few universities are so well-matched to the objectives of the Centers that success can be assumed in the absence of careful program planning.

Under subsection (c)(3), this subsection appropriately recognizes that these Centers should be revenue-producing without indicating that they become self-sustaining. Total self-sufficiency would force the Centers to abandon nonrevenue-producing activities (basic research and education), and to focus only on those activities that would produce revenue.

Section 6, subsection (d) authorizes the Director to make nonrevenuable planning grants for the development of a program plan. As noted previously, careful planning is necessary to insure the development of an adequate program plan. A number of hard questions need to be answered prior to establishment of a Center. Such planning will be costly, and few universities will be willing to devote the necessary resources to such an activity on a speculative basis. The alternative would be to postpone some or much of the planning until after the Centers are established.

Section 6, subsection (e) may be one of the most crucial provisions in this legislation. Unanswered questions about government rights or inappropriate claims to rights could cause this program to be avoided by both industry and universities. In other words, the entire program could fail unless this subsection is carefully thought out. This is one of those points at which it is crucial to remember that the objective of this legislation is to stimulate industrial innovation for the well-being of people. Patents gathering dust in government or university archives contribute little to that objective. Subsection (e) should be amended as follows: ". . . each Center has the option of acquiring title to any invention conceived or reduced to practice under the auspices of the Center that was supported in a material way by Federal funds. The Director is authorized to delegate to the Centers the responsibility for determining if it fact an invention was first conceived or reduced to practice under Center auspices, and if in fact the invention was supported in a material way by Federal funds."

Subsections (e) (1)–(7) are essential to insuring an intelligent policy toward government rights in inventions. Subsection (e)(3) is particularly important, i.e., without the flexibility to grant non-exclusive rights, significant technologies which require a substantial investment to bring to the marketplace, will go begging. It is an inescapable fact of life that innovation is expensive. The cost of bringing one new technology or product to the marketplace could easily exceed the total amount authorized under this legislation. No firm or venture group will make a major investment on a non-exclusive basis. Competitors need only to secure a license, and through reverse engineering (or marketing), piggy-back on the developmental efforts of the first license holder. In other words, the latecomers are able to reduce their cost of development or entry into the marketplace, thereby gaining a competitive advantage over the first license holder.

Section 7 outlines conditions pertaining to grants and cooperative agreements. For the most part, these conditions are appropriate, with the exception of subsection (a). This provision implies that the Federal Government should not pay the entire cost of the program. The 75 percent level of funding is proper. However, the nature and source of the remaining 25 percent is not specified. Consequently, it is likely that in many, if not most, cases this contribution will be made "in kind"—a contribution which is often more illusionary than real. Operating under the philosophy that someone—the university or industry—should make a hard dollar commitment to this effort "in kind," contributions should be limited to one-half of the remaining 25 percent.

Section 8, which outlines the administrative arrangements, is, for the most part, in proper form. Consideration with other departments and agencies is absolutely essential, for two reasons. First, there is an overlap of missions and interests. This program can be of significant value to others in reaching their objectives by providing a focal point, stimulating technological innovation in a number of critical areas. For each agency to attempt to do so in its own right would be confusing, counterproductive and expensive. Second, some of these agencies, such as the National Science Foundation through its experimental Innovation Centers and Cooperative R. & D. Centers, have had considerable experience in this area. Their experiences—their successes and failures—provide a useful foundation upon which to build their programs.

Section 9 provides for appropriate informal citizen involvement in the program. Hopefully, this panel will represent a diversity of backgrounds, and both large and small businesses and institutions.

The level of funding authorized to be appropriated under Section 10 is realistic. Considering Section 6, first subsection (a), the $40 to $60 million level represents a reasonable compromise between the need for incentives to industrial innovation and the ability of the university community to absorb this funding in an effective, efficient manner. Given the high cost of industrial innovation, and the fact that many corporate R. & D. budgets exceed this level of funding many times over, more could be spent in stimulating industrial innovation. However, the thrust of this program is contrary to the direction of many universities. Applied research is not held in high regard on many campuses. Developing a host environment which encourages innovative activities, is willing to take risks, and will reward applied research, will take time and careful planning. If this isn't done early in the program, 1984 will arrive with the basic issues still unreached. The number of universities which will be willing and able to make the adjustments which have the necessary resources does not warrant a higher level of funding than contained in Section 10(a).

Given the need for research and careful program planning, the $10 million funding level specified in Section 10(b) is appropriate. Similarly, subsection (c) provides the Director with the flexibility to expand funds as they are needed, and not as they are appropriated.

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## "Coupling Industry and University to Stimulate Technological Innovation"*

### INTRODUCTION

There has, in recent years, been an increasing concern over the rate of technological innovation in the United States. There is evidence of a decline. The reality of this decline is, in a sense, a moot question. The real issue is the ability of technological innovation to keep pace with the social, economical and environmental need for innovation. In this respect, there is no question that an increase in technological innovation is urgently needed.

One of the devices for helping to bring about that increase is the coupling of industry and university under federal sponsorship. Legislation to this effect has been introduced by Senator Stevenson and others under the title "The National Technology Innovation Act of 1979" (S. 1250). This paper will not address this legislation, but rather, will examine the concept of coupling industry and university in a joint effort to bring about an increase in technological innovation.

### THE IMPORTANCE OF TECHNOLOGICAL INNOVATION

In a very real sense, the decade of the 1970's represents a sort of "technological watershed." Technological innovation has, in the past, been one of the cornerstones of modern civilization. We have coveted technological innovation because it led to a higher level of living. For example, electricity has expanded our productive capacity and extended the hours of human activity; the automobile greatly facilitated travel and transportation; radio made a worldwide communication feasible and inexpensive; and X-ray advanced medical technology and has saved countless lives.

The history of the United States is intertwined with the history of invention and innovation. In modern societies, there is virtually no area which has been untouched by technological innovation.

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This interdependency will continue into the future. As we face the 1980's and beyond, technological innovation will play an even more critical role in maintaining our current standard of living and, perhaps, the basic fabric of modern civilization.

Without innovation, we face a future of inevitable decline. As a matter of national policy, we must continue to innovate at an increasing rate if we are to achieve solutions to social, economic, environmental and material-shortage crises.

### THE DECLINING RATE OF U.S. TECHNICAL INNOVATION

High investment costs, new governmental regulations and controls, increasingly sophisticated technology, complex marketing procedures and shortened product life cycles have caused some observers to conclude that American innovation is breaking down. Unfortunately, this is happening just at a time when technological innovation is urgently needed.

Supporting this contention are some alarming national trends:

*Patents*

We now rank fifth in the number of patents issued on a per capita basis. Four countries (Japan, Sweden, Germany and Switzerland) now issue more patents on a per capita basis than the United States (which is on par with the Soviet Union).[1] The percentage of patents issued to private citizens has decreased by 22 percent since 1963. In that year, independent inventors accounted for 27 percent of all patents granted; today, it is running about 21 percent.[2] In addition, the number of United States patents granted to foreign nationals has increased 85 percent and now accounts for about 23 percent of the patents issued.[3]

*Rate of technological innovation*

The American rate of technological innovation appears to be decreasing.[4] In the machine tool industry, for example, the United States has lost its position of leadership and now trails behind West Germany, Japan and France. The United States equals Russia in machine tool production, but they produce better equipment.[5]

*New product failure rate*

New product failure rates remain high. It is estimated that between 37 percent [6] and 80 percent of all new products fail.[7]

*Productivity*

The United States now ranks 11th in its rate of productivity increase among the eleven developed nations. American growth in productivity from 1960–1973 was 3.4 percent annually. During the same period, European productivity increased 5.7 percent and Japan increased at the rate of 10.5 percent per year.[8] In a few years, American output per worker will slip behind that of West Germany, Japan and France. There has been little or no growth in productivity in the retail industry and little in manufacturing, but there have been substantial increases in agriculture. In the latter area, the United States has the highest level of productivity and the highest rate of productivity increases in the world.

*New equity issues*

The number and value of new equity issues has decreased from 1300 new issues valued at $3.3 billion in 1969 to 24 new issues valued at less than $.3 billion in 1977.[9]

*Capital investment*

American capital investment per worker is down. We currently spend $223 annually per worker. Japan spends $336 and West Germany is investing in new plants and equipment at the annual rate of $700 per worker.[10]

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[1] "Is American Genius Being Stifled?", U.S. News & World Report, December 23, 1974, at 46.

[2] Haber, "The Decline of the Better Idea," The Sciences, October 23, 1974, at 46.

[3] Lein, "Synergistic Effects through Licensing," Les Nouvelles: J. Licensing Executives Society, December 1975, at 223.

[4] "The Breakdown of U.S. Innovation," Business Week, February 16, 1976, at 56.

[5] Address by Henry Warren, University Business Development Center Advisory Meeting, Scottsdale, Arizona, January 17, 1977 (hereinafter cited as Warren).

[6] Booz, Allen & Hamilton, The Management of New Products 12 (1968)

[7] "New Products: The Push in on Marketing," Business Week, March 4, 1972, at 38.

[8] "Statement of Mitchel P. Kobelinski Before the Senate Select Committee on Small Business," 95th Congress, 1st Session (1977).

[9] The Utah Innovation Center, Salt Lake City, Utah: Utah Innovation Center, University of Utah, ND, NP.

[10] Warren, supra note 5.

*Research*

Since 1968, total government and industry research spending has dropped more than 6 percent in real (non-inflationary) dollars. During the last decade, the real industrial investment for basic research has slipped 12 percent and federal funding on industrial basic research fell 45 percent.[11]

*Natural resources*

Supplies of natural resources are diminishing. For example, 1976 world oil production was 57,210,500 barrels per day. At that rate of consumption, proven world reserves of 598,990,320,000 barrels will last less than thirty years.[12]

*Balance of payments*

Since about 1970, the United States has experienced a negative balance of payments.[13] As our dependency on external sources of supply for basic raw materials (such as oil) increases, we will become increasingly dependent upon the export of technological goods and services to offset our imports of raw materials.

The total current annual industrial investment in innovation probably is somewhere between $39.7 billion to $51.7 billion:

Private R. & D. expenditures for 1975 are estimated at between $11.9 billion and $15.5 billion.[14]

R. & D. expenditures are estimated to account for about 30 percent of the total cost of developing a new product.[15]

Booz, Allen and Hamilton estimate that about two-thirds of this investment is committed to new products which are either dropped before market introduction or fail to produce a satisfactory return.[16]

The high cost and risk of innovation has caused many firms to reduce their R. & D. activity and to focus on product improvement rather than product innovation. According to Business Week, one of the prime villains in the breakdown of American innovation has been the no-risk, supercautious attitude of management. The economic impact of a more cautious management approach to innovation is illustrated by a comparison of the performance records of five leading high technology innovators (IBM, Xerox, Texas Instruments, 3M and Polaroid) and six typically mature or less innovative firms (Bethlehem Steel, GE, DuPont, P&G, General Foods and International Paper). From 1945 through 1974, the annual compounded growth rate of the innovators was 16.5 percent in sales and 10.8 percent in jobs. For the non-innovators, the corresponding increases were 7.8 percent in sales and 1.9 percent in jobs.[17]

There is an obvious need, then, to stimulate innovation in order to counteract this apparent management conservation, and existing trends of technological breakdown. While there is good evidence that technological innovation is declining in the United States, it is not clear as to how we should go about reversing this trend. As a first step in this direction, it is appropriate to distinguish between invention (research and development) and innovation (commercialization of technology).

## DISTINGUISHING BETWEEN INVENTION AND INNOVATION

The words "invention" and "innovation" have created a considerable amount of confusion. Perhaps one of the reasons for this confusion is that they have been used as equivalents. Before examining the sources of technological innovation, it is appropriate that we pause to distinguish between "invention" and "innovation."

The patent system is designed to grant certain legal rights for inventions; that is, technological, intellectual property that is novel and non-obvious.[18] Unfortunately, public law sometimes treats certain stages of the innovation process as ends unto themselves, rather than as means to an end.

An invention—a new concept, discovery or device—is only the beginning. It has value only if it is put to use by society as (1) a building block for further developments (i.e., inventions) or (2) a new process, product or service (i.e., innovations). All of those activities, including invention, which precede the innovation are part of the

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[11] National Science Foundation, National Patterns of R. & D. Resources (1973) (hereinafter cited as R. & D. Resources).

[12] "Worldwide Oil and Gas at a Glance," Oil & Gas Journal, December 27, 1976, at 105.

[13] "30 Int'l Financial Statistics," 370-371 (1977).

[14] R. & D. Resources, supra note 11.

[15] Booz, Allen & Hamilton, "A Program for New Product Evaluation, Product Strategy and Management" 339 (ed. T. L. Berg and A. Shushman, 1965).

[16] Id.

[17] "The Breakdown of U.S. Innovation," supra note 4.

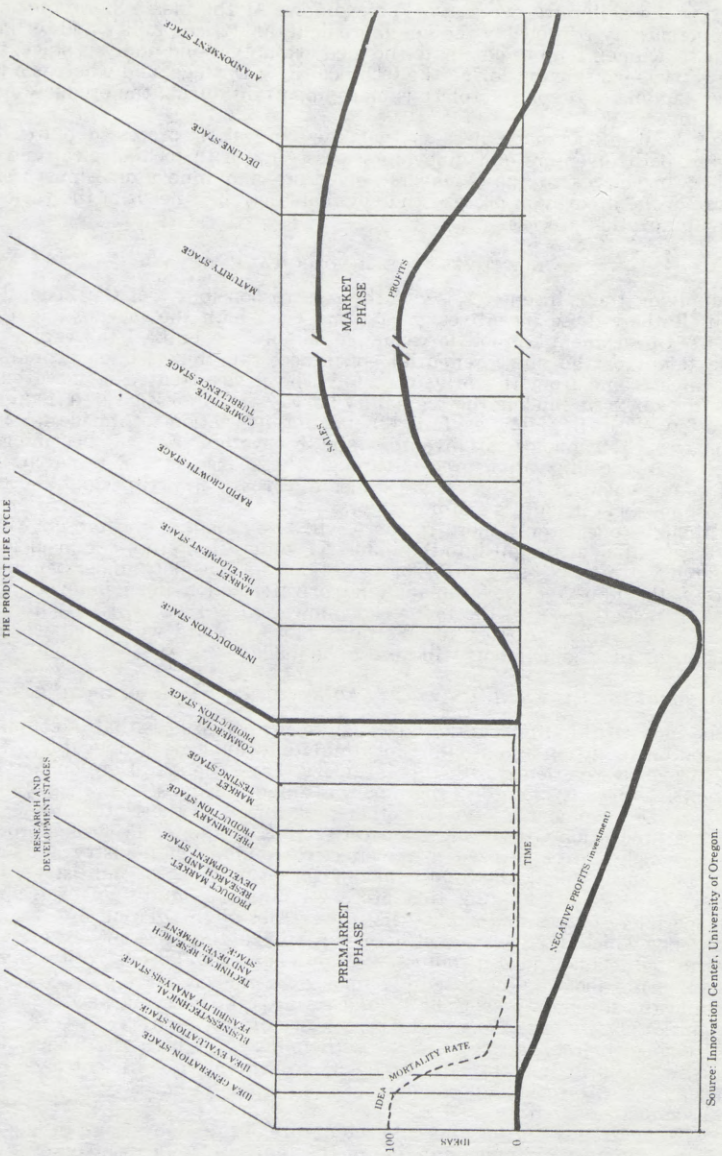
[18] 35 U.S.C. §§ 100-104 (1970).

innovation process. Therefore, while invention is a necessary precedent to innovation it is not sufficient to complete the process.

Hence, an innovation is ". . . a complex series of activities, beginning at first conception where the original idea is conceived, proceeding through a succession of interwoven steps of research, development, and management decision making . . . culminating when a product, which might be a thing, a technique, or a process, is accepted in the marketplace." [19]

This definition is illustrated in Figure 1.

[19] Johnson, "Inventions, Innovations and Incentives," The Public Need and the Role of the Inventor 6 (National Bureau of Standards, 1976).




Source: Innovation Center, University of Oregon.

**Figure 1**
**The Innovation Process**

Inherent in the innovation process is the fact that at the different stages, different types of skills are necessary. For example: At the idea generation (invention) stage, creativity is probably the key ingredient; analytical ability and technical and business acumen tend to dominate the idea evaluation and analysis stage; technical know-how is paramount during the technical R. & D. stage; and whereas a thorough understanding of the marketplace is more important during the product (market) R. & D. stage.

The point to be made here is that the innovation process requires different players, both inventors and innovators, possessing both technological and business skills.[20] Incentives to these players—inventors and innovators—must reflect the nature of the innovation process, thereby matching their needs at the various stages of the innovation process.

### INCENTIVES TO TECHNOLOGICAL INNOVATION

Supplying these incentives is not the sole responsibility of the Federal Government. Rather, these incentives must come from both the private and the public sectors. Government cannot, for example, supply the bulk of the capital, the creative talent or the entrepreneurial spirit necessary for technological innovation. This must come from the private sector. The government can, however, provide incentives by: (1) reducing the regulatory barriers to innovation in a manner that is consistent with the public welfare; (2) enacting legislation to provide tax and other incentives to technological inventors and innovators; and (3) becoming directly involved in the innovation process through the sponsorship of research, education and management and technical assistance to corporate, institutional and unaffiliated technological inventors and innovators.

Although considerably more research will be needed, at the present time we do not have sufficient insight into the industrial innovation process. Considerably more research will be necessary in order to develop an adequate understanding of that process, the impact of government (and private) action upon innovation, and the effect of incentives upon the industrial innovation process. This research will take time. We can ill afford to wait. We must move forward with what we now have, recognizing that adjustments will need to be made.

### COUPLING INDUSTRY AND UNIVERSITY TO STIMULATE TECHNOLOGICAL INNOVATION

One incentive that appears to have significant potential is that of coupling industry and university in a joint effort to stimulate technological innovation. We are not without some experience with this incentive. The Economic Development Administration's University Center Program; the Small Business Administration's Small Business Development Center and other programs, and the National Science Foundation's Innovation Center and Cooperative R. & D. Center Programs provide experience which can be utilized in an effective coupling of industry and university.

As previously noted, the industrial innovation process is a multistage, interdisciplinary process. Stimulating this process requires a multitude of technical and managerial resources and skills. The universities of this nation are a vast pool of knowledge which, if effectively utilized, can provide the necessary expertise to assist unaffiliated technological inventors, entrepreneurs, smaller enterprises and corporations to bring about an increase in technological innovation.

While the ultimate responsibility and rewards for carrying new technology into the marketplace must belong to the private sector, universities can—

(1) engage in cooperative R. & D. with industry at both the basic and applied levels, where private sectors are necessary to generate a sufficient level of R. & D. to keep pace with societal, economic and environmental needs;

(2) conduct research to—

(a) develop better insights into the nature of the innovation process;

(b) enhance our understanding of the impact of industrial innovation on the well-being of the citizens of this and other countries;

(c) improve our awareness of the relationship between industrial innovation and the actions of both the public and private sectors; and

(d) develop more effective and efficient tools and techniques for stimulating technological innovation;

(3) offer educational opportunities for traditional and non-traditional students oriented toward invention, entrepreneurship, venture capital, smaller enterprise management, management of R. & D., and new product development and commercialization;

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[20] For additional information on the nature of the innovation process, see E. A. Pessimier, Product Management (1977).

(4) provide management and technical assistance to technological corporations and smaller enterprises.

Universities represent a neutral ground upon which competitors can meet to solve common problems and through which federal assistance can be channeled. University faculty represent a variety of technological and commercial disciplines. For this reason, they are our best bet for a broad-based attack on the declining rate of technological innovation.

INSTITUTIONAL BARRIERS TO EFFECTIVE IMPLEMENTATION

There are, however, a number of institutional and academic barriers to implementation of an effective industry-university partnership.

From the industry side, some members of the private sector do not hold universities in high regard; i.e., they are viewed as being too esoteric, incapable of innovative and entrepreneurial thought and action, and as not being interested in the business of business. These problems are largely attitudinal and represent more of a challenge than a barrier.

Harder to deal with are the barriers arising out of the basic differences between the industrial and the academic communities. The goals and objectives of the two groups—profits versus the pursuit of knowledge—are not well-matched. Industry lives in a world of short-term needs, whereas academia exists in a long-term environment. Both must be willing to adapt to the needs of the other.

From the academic side, there is oftentimes a disdain of applied research and active interface with the public sector. Courses oriented toward entrepreneurship and small business have grown rapidly in the last ten years, but are still offered in a relatively small percentage of the nation's business and engineering schools. Faculty reward systems are frequently oriented toward publishable research, with public service and applied research being virtually ignored. Many, if not most, universities attach little significance to the granting of a patent in their faculty reward and tenure policies. Similarly, publications in professional journals and publications outside the discipline frequently receive little recognition from one's departmental peers. In addition, corporate managers hold no monopoly on what Business Week calls "a super cautious attitude." University administrators and the faculties they represent often excel in this area.

These barriers do not bar the effective coupling of industry and university to stimulate industrial innovation. They do, however, make this coupling more difficult. The lessons learned from the programs mentioned above and from the cooperative extension service suggest there are some institutional ingredients in effectively implementing this concept.

KEY INGREDIENTS FOR EFFECTIVE IMPLEMENTATION

There are at least nine key ingredients:

1. *Involvement of industry in the planning and implementing stages.*—Problems which fail to involve the participants in the planning and implementing stages fail with nearly consistent regularity. Involvement of industry must occur at both the Federal and university levels. Failure to do so can result in (a) alienation of industry, and (b) misdirected programs. First, university extension program planners have learned through experience that early participation is essential to program legitimization and clientele involvement. Second, industry involvement is essential to insure that industrial innovation becomes the primary objective. Academics have a tendency to design academic programs. Applied research and technical and commercial assistance are likely to be understated without a strong industrial input.

2. *Strong program leadership at the Federal level.*—Strong program leadership at the federal level is essential for effective program inplementation. The use of the word "leadership" is intentional here. Both partners in this coupling—industry and university—are in no mood for strong program control. Control stifles flexibility, which inhibits creativity, which kills innovation. The absence of control will encourage both partners to develop programs that will benefit them instead of the public. On the other hand, strong federal leadership can insure proper program development without burdensome controls, and provide a neutral ground for conflict between the two partners. This leadership must have an understanding of the industrial innovation process; be capable of relating to industrial needs; be able to relate to and coordinate with other federal programs and agencies; and must understand the nature of universities, their administrators and faculties.

3. *The presence of both technical and commercial resources.*—Traversing the industrial innovation process isn't, as noted earlier, a function of technology or commer-

cialization. It is both. Programs based on purely a technological base are more likely to experience a high rate of failure in the marketplace; whereas those based solely on business school involvement are more likely to engage in incremental improvements than in technological innovation. Universities which are fortunate enough to have both business and technological schools must incorporate both into their plans. Universities lacking one resource or the other must develop effective intra-institutional ties to insure that the deficient area is covered.

4. *Strong university administrative support and backup.*—University-based centers—the basic device for coupling university and industry—are themselves an innovation. To date, only the NSF Experimental Innovation Centers have attempted to combine research, education and public service in a single program. Others, such as EDA's University Centers, have tended to be non-academic management assistance appendages attached to universities. Thus, the concept of technically-oriented programs of basic and applied research, entrepreneurially-oriented education, and technical and commercial outreach in a close partnership with industry is a new beast—one which will either fail or suffer from high inefficiency unless strong administrative support is forthcoming from the high echelons of the university.

Since these centers represent a substantial departure from the academic status quo, strong faculty support, except in relatively rare cases, should not be expected. This makes administrative support at the dean and presidential levels imperative.

The universities must be willing to take risks; to see their names linked with business failures, programs that don't work, technology that doesn't seem feasible at first glance, or courses that appear (to some) to be non-academic. True innovation is risky business. Unless administrative support is forthcoming, centers are likely to experience "burn-out" of their staff, faculty disinterest and non-involvement, a shift toward incremental innovations and safe technology, and the evolution of a "super-cautious" management attitude—the bane of creative thinking and entreneurial action.

With strong top and college/departmental administrative support, centers can draw upon the interdisciplinary resources of universities to engage creative basic and applied research; offer new educational programs for students with an interest in charting their own course independent of the nation's corporations; pursue the commercialization of university-educated technology; and provide private sector inventors and innovators with commercial and technical assistance.

5. *The presence of an academic product champion.*—Although non-academics, i.e., business and professional people, should be involved in center programs and key leadership positions, effective linkage with the academic community requires the involvement of an academic "product champion."

Like all other innovations, this concept must have its "product champion"—within the academic community. Innovation centers are rarely popular initially for the simple reason they represent a deviation from the status quo—which equates with risk. Most people are averse to risk and are not prone to follow entrepreneurial leadership. Academics are certainly no exception to this rule. New ideas, concepts and problems, like new products and ventures, need someone who is committed to the innovation and willing to carry it forward alone if need be and at personal risk.

In an academic setting this risk may come not in the form of one's personal fortune, as in the private sector, but in the form of his or her academic standing. The innovation process cannot be carved up and distributed into departmental niches. It must be created in its entirety. Thus, involved academics must, to an extent, step out of their departmental roles into a broader intradisciplinary setting. This, as will be seen below, involves some risk.

If past experience is any indication, these "product champions" will leave their mark on their programs. They will heavily influence program direction and evolution, the nature of the research carried out, the educational program and interface with industry. They, and other program leaders, should be chosen with care.

6. *A faculty attitude which tolerates interdisciplinary research and applied activities.*—The concept of coupling industry and university on a joint effort to stimulate technological innovation isn't going to be uniformly accepted in the academic community. Some faculty are opposed to any industrial or commercial involvement. Others view applied research and outreach as the antithesis of the true function of a university. Some faculty will be threatened by this concept. Still others, seeing no opportunity for personal involvement, will be apathetic.

Some universities will not be suitable host institutions because of faculty (and/or administrative) attitude. In a hostile or apathetic environment, program success is not likely to generate support. For example, if applied research is deemed to be of little or perhaps even negative value, successful launching of a new technology or a

new venture may bring few rewards. Ultimately, programs which do not enjoy tolerant, if not supportive, faculty attitude, will fail.

7. *A compatible faculty reward and tenure policy.*—Closely related to faculty attitude is the requirement that the faculty reward and tenure policy be compatible with the objectives and application of technical and commercial know-how to promote industrial innovation. If faculty reward and tenure policy is heavily oriented toward research and the publication of that research in major academic discipline-oriented journals, faculty will not engage in applied research and application activities. Those that do will, over the long run, be negatively rewarded. This is particularly serious for non-tenured faculty.

It is essential that universities resolve reward and tenure problems. Failure to do so will virtually insure faculty non-involvement and eventual program failure. This is not to say that all university faculty reward and tenure policies are incompatible, but it is likely to be a frequent problem.

8. *A realistic patent policy.*—From the perspective of industry, the key ingredient may be that of a realistic patent policy. Innovation is a costly business. Normally the bulk of the costs associated with the development and commercialization lie beyond the invention and initial R & D stages. Where these costs are high—and they usually are in the case of major technological innovations—industry is not likely to invest in inventions which are open to all comers on a non-exclusive basis. To do so would place them at a competitive disadvantage. For example, assume firm "A" spends $100 million (not an unreasonable figure) in commercializing a new technology. If firm "B" can, through imitation, reduce its cost to, say $40 million, it has gained a significant cost advantage over firm "A". It can pass these savings on to its customers, possibly gaining sufficient advantage to overtake and perhaps overwhelm firm "A". A non-exclusive license policy encourages imitation—not innovation. At a minimum, innovaters should be permitted sufficient exclusivity to regain their investment plus a reasonable profit on that investment.

In addition, the question of government rights should not apply unless the invention was first reduced to practice under a project in which a significant federal investment was involved. Unless corporate and noncorporate inventors and innovators are permitted to obtain assistance without jeopardizing their patent risks, they are not likely to become involved. In short, the "industrial" partner could be lost through an unrealistic patent policy.

9. *Adequate funding over an adequate period of time.*—From a university perspective, adequate funding over an adequate period of time may be the most crucial ingredient. Many universities have become leery of programs which provide only start-up funds or "seed money." Too frequently, these funds are sufficient to generate a demand for the program, leaving the university to provide funding or cancel the program. Some universities, having once been bitten (several times over), would pass over attractive programs rather than fall into this dilemma again. Similarly, their faculty are not likely to invest their time and effort in a program with a short-term future.

Universities and their faculties are not likely to be attracted to programs that involve out-of-pocket costs on their part. Inflation and declining enrollments have generated a financial crisis at many institutions. New programs requiring a financial investment are likely to be spurned. This does not mean that the federal government should incur the total cost. A better alternative is a combination of federal, state and industrial funding.

This does not exhaust the list of factors to be considered in coupling industry and university to stimulate technological innovation. They are, however, among the key ingredients which, if not properly addressed, can have a significant negative impact. Conversely, properly attended to, these factors become ingredients for success.

## CONCLUSION

Technological innovation is not keeping pace with a growing list of national and international social, economic and environmental problems. In addition, despite the seriousness of the problem, our understanding of the nature of the industrial innovation process, its impact upon us and our impact upon it, is limited.

It is, however, clear that we can ill afford to wait until we fully understand the industrial innovation process to begin to stimulate technological innovation. New incentives are clearly needed now. Once such incentive is the concept of coupling industry and university under federal sponsorship in a joint effort to conduct basic and applied research, provide innovation-related educational opportunities; and develop programs to provide technical and commercial assistance to all segments of the private sectors. The fit with the academic environment is not a perfect one, and adjustments will be needed. However, the problems are known and are solvable.

With proper implementation, the substantial technical and commercial resources of universities can be combined with the resources of industry and government to create a new environment in which the creative and entrepreneurial talents of individuals, industry and institutions can be focused to stimulate technological innovation.

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AMERICAN CAN CO.,
*Greenwich, Conn., June 28, 1979.*

Hon. ADLAI E. STEVENSON,
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: I am writing in response to your memorandum of June 8, 1979, regarding Legislation on Industrial Innovation.

We are very pleased by the interest of the Subcommittee on Science, Technology, and Space in a very serious problem—the decline of innovation in the United States. As you noted in your speech on the subject, S. 1250 is only a first step toward solving the underlying problems that have led to this decline. We are prepared to support this Bill because of the symbolic value of a first step. However, as you yourself noted in your comments, we cannot expect major results simply through the creation of another government unit, nor through the technological contributions from a new increment in federal R&D spending.

The causes of American technological decline are well documented. Briefly, we believe the most serious are regulation (and accompanying uncertainty concerning unknown future regulation), tax structure (especially in the capital gains area), inflation (which has serious consequences for innovation, but many other ramifications as well).

I could write at some length on each of these subjects; however, there appears to be a strong consensus within American industry on these points, and I would recommend, if you have not already done so, that you contact the Industrial Research Institute and invite them to comment or testify on S. 1250, and the need to go much further in eliminating governmental disincentives to industrial innovation. Most industrial research managers believe that the elimination of disincentives will do far more for American productivity than programs to create new incentives. The IRI can be contacted through its president, Dr. Jason M. Salsbury, at 100 Park Avenue, New York, New York 10017.

Please let me know if the American Can Company can further contribute to your efforts to get our country back on the track.

Sincerely yours,

WILLIAM J. SMITH.

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THE AMERICAN SOCIETY OF INVENTORS,
*King of Prussia, Pa., June 29, 1979.*

Hon. ADLAI STEVENSON,
*Committee on Commerce, Science and Transportation,*
*Subcommittee of Science, Washington, D.C.*

DEAR SENATOR STEVENSON: Representing the American Society of Inventors and also that group's forming coalition, the National Congress of Inventors Organizations (NCIO), I wish to inform you of our support, particularly with respect to provisions thereof applicable for the establishment of centers for industrial technology in Universities and non-profit institutions. We feel it is particularly important to provide independent inventors with technological resources to draw upon as needed.

We ask that this support in favor of this bill be made a matter of record.

Respectfully,

HAROLD E. MCKELVEY,
*Executive Secretary.*

CARNEGIE-MELLON UNIVERSITY,
CENTER FOR ENTREPRENEURIAL DEVELOPMENT,
*Pittsburgh, Pa., July 3, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space,*
*U.S. Senate Washington, D.C.*

DEAR MR. CHAIRMAN: With your permission I'd like to add a clarifying statement to my written testimony. This is in response to a question asked by Senator Schmitt at the first session of this subcommittee meeting on S. 1250. Senator Schmitt was interested in the government laboratory or NASA model for improving technological innovation.

Following the paragraph beginning on page 10 and ending on the top of page 11 of my testimony, the appended, clarifying paragraphs to this letter should be added.

In order to not create a misunderstanding, the appended letter from Dr. Shaw on my written testimony should have has name typed over the resume on the back of his letter to correctly identify his credentials.

Respectfully,

DWIGHT M. BAUMANN.

Enclosure.

In contrast to the quasi-university laboratories that were primarily developed in the aerospace era, the university laboratory has two products: published research and qualified practitioners. Since many of the subtle issues of scientific and technical intuition are useful to new product development long before they are describable and available in the format required for formal, reviewed publication, there is considerable advantage in having the so-called "technology transfer" be via the entrepreneurial efforts of the same technologist that developed the technology. These people usually stay located in the same place where they started even when they change their organizational affiliations. This develops an indigenous industry. One technology has been totally reduced to formal reports, it is really a gift to the whole world because it crosses the ocean as fast as it crosses the city.

The requirements of publication to give the "idea" to society also protects against the possibility that someone else will file a patent. This may often be a motivation of even those practitioners who would desire to leave the governmental research organization to start their own technological firm to practice the art. They can give several other reasons. Usually they would be uncertain of their ability to negotiate an acceptable license with the government because of all the conflict of interest concerns. By publishing broadly, they also reduce the peer pressure that may result if they did not make every attempt to be and to appear to be virtuous. Finally, most of the present legal and professional ethics rules require that the technology belongs to the employer at the time of conception. The mechanisms for transfer of that ownership are so complex that legislative attention is required to establishing new mechanisms if time to transfer technology from the laboratory to the marketplace is truly "of the essence."

In short, there is evidence that some very few universities have had a direct relationship as change agents in the developments of local high technology industries. In contract, the agricultural research laboratories and the other related, more recent governmental laboratories do not appear to have the same immediate geographical effects on related manufacture and chemical production. Agri-chemicals and machines, and AEC suppliers appear to have been located on the basis of transportation costs in the former and political considerations in the later. Also the agricultural research results were often directly related to their own specific areas of the U.S. and thus there did not seem to be rapid international transfer of agricultural developments. The plant breeding and disease control technologies had to be applied to each foreign location and thus people had to be trained in the techniques and migrate to other parts of the world in order to accomplish the technology transfer.

As compared to the case of international transfer of agricultural technology, NACA dealt with an industry at a time when there were few well-trained technologists within the industry. Much of the aircraft industry at that time had been developed by barnstormers and mechanics to whom mathematical and experimental modeling and scaling techniques were a mystery. There were very few Ph.D.'s in applied science or engineering at that time, and NACA was able to attract a significant number of them. The U.S. aircraft industries at that time were in a growth stage so there was little concern with the technology transfer to foreign countries. Except in those topics where secrecy orders were established in NACA, we can be sure that the World War II aircraft developments in Japan and Germany

were significantly aided by NACA. The fact that the NACA centers provided trained technologists for U.S. aircraft developments during the crisis of World War II plus a more dynamic population and more natural resources may all have evolved the superiority of the U.S. aircraft.

In the cases of the cooperative research laboratories such as the Mellon Institute, Battelle Institute, Armour Research (now I.I.T. Research) and others, there has been strict secrecy when developing proprietary products under industry contract. The patents were totally assigned to the sponsor. It is unclear that a mechanism could be developed to provide the industrial secrecy in a government sponsored research project in either a government or a private or nonprofit laboratory at this time. Absent that, patent policy even more exclusive than S. 1250 provides may be necessary. Certainly an aggressive foreign patenting and licensing policy should be a part of the activities associated with S. 1250. Since it is unlikely that sovereign states would now accept a policy of the U.S. refusing to grant patent licenses, some mechanism would need to be developed to provide control or some remuneration to compensate the U.S. for the R&D costs. The best alternative seems to be to develop the "trade-secret" approach and to realize the powerful multiplicative forces of developing more well-prepared, indigenous technologists.

If cooperative research centers, as contrasted to innovation centers, are to be developed under S. 1250 they should be restricted to being at universities and should primarily be staffed by graduate students. These students will then transfer the technologies into the industries that finally employ them. The innovation center concept can develop without the cooperative research centers because there is a small, but already significant amount of technology that does not have enough market-pull to be attractive to large industries. The fact that a few universities have been moving in the direction of applications to civilian and urban technologies should be rewarded and set up as an example to change the focus of other universities. The more rapid transfer of both industrial and service technologies to the marketplace, the better.

It appears strange that the media, social activists, and governmental leaders should be so concerned about patent ownership when the normal, free market royalty on even the best patents is on the order of a few percent of the selling price and yet 30 to 80 percent of the corporate profits that might be generated by a patent monopoly are directly returned to government via corporate and personal income taxes. If a 50 percent partner of mine who did no work in my company asked me for 1 percent royalty because of something he had done in the past, I would tell him where to go. And it wouldn't be to Washington—that would be a second choice.

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THE UPJOHN CO.,
*Kalamazoo, Mich., July 3, 1979.*

STEVEN FLAJSER,
*Subcommittee Staff, U.S. Senate, Committee on Commerce, Science, and Transportation, Washington, D.C.*

DEAR MR. FLAJSER: I am responding to Senator Stevenson's memorandum of June 8, 1979, regarding legislation or industrial innovation.

In my view, the bill does not distinguish adequately between the discovery process and the multiple steps that must be achieved in order to move that understanding to general utilization. Not only innovation from discovery but also the dissemination of innovation must be considered.

The centers for industrial technology, on first inspection do not differ significantly from similar centers already established through the National Science Foundation—for instance, at M.I.T. I do not recognize the advantage of having two separate legislative authorities for activities that appear to be identical.

I really have no detailed knowledge of the status of the Presidential Review Memorandum related to the development of technology and its utilization by industry. It would seem to me that the substance of S. 1250 is not unrelated to the substance of that memorandum. It would seem to me reasonable that, if possible, the legislation might include some level of responsiveness to the extensive contributions that have been made by industry and by academia to the development of that memorandum.

There is to my knowledge no evidence that the rate of discovery has diminished in the United States. The cost of translating discovery into feasible technology has become both lengthy and uncertain for a variety of reasons, mostly related to the lack of any institution whatsoever in the United States within which the capacities of government, industry, and academia can be jointly exercised toward common

goals. There is an absolute lack of the equivalent of the Office of Naval Research or the National Research Council and its contributions during World War II. Countries such as Japan and Germany have well-developed cooperative traditions. If one contrasts the Japanese response to the potentials of recombinant DNA work with that of the response in the United States, then a most illuminating contrast is revealed. This contrast can be iterated in almost every single realm, from nuclear physics to sociology. It is my impression that the legislation does not address this issue.

It is in my view the entire system, from basic research to the social and economic impacts of full-fledged dissemination of innovation, that must be studied. To pick out a portion of this system, however, important, is to distort the nature of the actual process. I am a part of one of the most innovative industries in the United States and have no misgivings about the importance of the portion of the total system that the bill addresses. However, I am deeply convinced that by failing to recognize the entire extent of the interactive system that one must respond to, the possibility of unintended and even regressive schisms is created. I am sure that none of this was in the minds of the authors, and that quite the opposite was the intent of the bill. My concern is that industrial innovation as such is only one part, and an intervening part, of a very much broader system. In the absence of a consideration of this entire system, emphasis on one module can be disruptive. The evidence that industrial innovation, as a component of this system, now represents the effective limiting element is unknown to me.

I hope these comments may be of some value. Please be assured of my continuing interest.

Cordially yours,

W. N. HUBBARD, Jr., M.D.

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SOCIETY OF MANUFACTURING ENGINEERS,
*Dearborn, Mich., July 5, 1979.*

Senator ADLAI E. STEVENSON, Jr.,
*Chairman, Subcommittee on Science, Technology and Space,*
*Russell Senate Office Building, Washington, D.C.*

DEAR SENATOR STEVENSON: I was pleased to be in attendance at your hearings on June 27 on S. 1250, the National Technology Innovation Act of 1979. I was particularly impressed with the testimony of Dr. Morrison of IITRI, and that of Dr. Branscombe, Chief Scientist of IBM. Both of them have zeroed in on the heart of what we need to accomplish in the United States today, and the Society certainly supports what they said.

We have had correspondence on various occasions in the past concerned with the problem of productivity. We sent you a copy last year of our initial position paper on "The National Role and Importance of Manufacturing Engineering and Advanced Manufacturing Technology." This paper deals with innovations and technology developments and applications.

We have since followed through with a more in-depth position paper that deals with the philosophy of the Cooperative Technologies Program of the Department of Commerce. Attached is a copy of this position paper entitled, "Cooperative Technology—An Action Alternative for Productivity Advancement." Appendix B lists the history of the Society of Manufacturing Engineers in the area of productivity since 1972. This is not done for credit or recognition, but merely to establish the credibility of our people who have been involved in the area of productivity on a massive scale. Many of our staff and volunteers have cooperated in the technical advice, input, and workshops, in cooperation with the staff of the Department of Commerce, in the development of both the philosophy and the concept of cooperative technologies. Additionally, our people have testified in favor of a cooperative climate in which technical innovation can take place.

The Society by no means minimizes the importance of basic research, feeling that this is essential to the ongoing cycle of development of our industrial products. But it also believes that we can talk all we want about the intangibles of productivity, climate, etc., but unless we are willing to create a specific positive climate in which the source of all our wealth in the United States, namely its industrial production base flows, we cannot lick inflation, create a more favorable export balance, be competitive in world markets, or solve either our standard of living or energy problems.

We are dedicated to the fact that there is a huge amount of basic research which has been developed, which has not been applied for many reasons. Trained personnel were lacking, visibility of the basic research was not a high enough level,

application represented too large a problem for single companies or industries in the face of uncertain taxation of trust climates, and a host of other items.

We firmly believe at this point that a climate of cooperation of government, industry and academia must be encouraged and from that will flow the indicated solutions to our other problems. We must make less effective the right of almost anyone today to say "no" to almost anything and bring it to a standstill, and instead put some strength behind those who have the fortitude to face up to hard work and the ability to say "yes" in circumstances less than 100 percent assured. The production and industrial base of the United States was not built by those powerful enough to stop progress and innovation, yet, without responsibility for outcome.

We will be very happy to continue to work with you and your staff and Subcommittee on anything that will promote a climate in which greater productivity for the United States can be achieved. Please feel free to call on us either for persons in this area who could testify on in-depth aspects, or to expand on any particular point that you see relevant or pertinent to the success of the creation of a cooperative climate here in the United States.

Sincerely,

BERNARD M. SALLOT,
*Director, Professional and Governmental Activities.*

Attachment.

COOPERATIVE TECHNOLGY—AN ACTION ALTERNATIVE FOR PRODUCTIVITY ADVANCEMENT

(Position Paper by: The Society of Manufacturing Engineers)

On May 8, 1978, the Board of Directors of the Society of Manufacturing Engineers (SME) issued a position paper entitled "The National Role and Importance of Manufacturing Engineering and Advanced Manufacturing Technology." This paper confirmed and reinforced the conclusions drawn in earlier studies conducted by the U.S. General Accounting Office. In so doing, it underscored the urgent need for a national commitment to productivity improvement through advanced manufacturing technology. The SME paper also recommended the strengthening of existing federal programs designed to alleviate the problem of declining productivity.

The position taken by SME in this paper was—and is—strongly supported by other technical societies and associatioins, and by acknowledged authorities on the productivity crisis. It is noteworthy that the SME paper was extensively quoted by the National Center for Productivity and Quality of Working Life in its final report, entitled "Productivity in the Changing World of the 1980's."

A strong—indeed, an undeniable—consensus has emerged. The consensus is that federal support, in one form or another, must be forthcoming if American scientific and technical superiority is to be restored. Further, this scientific and technical superiority is an imperative if the nation is to attain the ancillary benefits of economic growth, an improved competitive posture in the world marketplace, and the technological capabilities necessary to an impregnable national defense.

The consensus is manifest. A consensus as to how government can best be involved is far less explicit. There are two strongly supported alternatives worth noting, however. They are as follows:

*Direct participation.*—Federal assistance in technological advance would be given through the funding of basic research through government procurement policies, through stimulation of innovative enterprises, and through assistance in technology transfer and manpower training for low-growth industries.

*Economic policy.*—Federal assistance would be given through a national economic policy designed to amplify the incentives and funding for expanded research and development. Included in this policy would be inflation control, tax credits, reduced regulatory constraints, and modification of antitrust and patent policies.

It is the contention of SME that these interrelated problems in productivity and innovation—as well as many of the alternatives for corrective action—have been well identified by industry for nearly a decade. However, the more recent inquiries and investigations have served (1) to clarify the need to coordinate technological advance with national social and economic goals, (2) to identify the industry segments that are not competitive in world markets, and (3) to identify blockages requiring federal policy adjustments.

Additional byproducts of these investigative efforts by Congress, the Department of Commerce, the General Accounting Office, the National Center for Productivity, and the Office of Technology Assessment have been the generation of relevant statistical data, coordinating techniques, and the development of people-skills essential to a continuing federal involvement in this crucial issue.

The present need—and it is a need of utmost urgency—is to establish an organizational mechanism to implement and apply these findings to a positive program for corrective action.

In its 1978 productivity position paper, SME suggested a restructuring of the Department of Commerce. It further suggested that the restructured department could serve as a focal point for affirmative action in implementing the position paper's advanced manufacturing technology program recommendations.

The Society has been encouraged by the Secretary of Commerce's formation of an Industrial Innovation Coordinating Committee charged with responsibility for the development of specific federal policy recommendations. This initiative has also generated a proposal for a Cooperative Technology consortium in which private enterprise, government, and universities would focus on fundamental technologies which underlie a wide range of industrial needs.

The Cooperative Technology Program,[1] to be administered by the Assistant Secretary of Commerce for Science and Technology, is a positive and potentially meaningful concept aimed at the improvement of industrial productivity. As presently perceived, the Cooperative Technology concept will stimulate action with respect to industry-identified technical needs related to basic or applied research. This research would be in areas of major national interest which are not adequately addressed by the private sector because of industry fragementation or a lack of market incentive.

Through the Cooperative Technology concept, the government would support, but not totally fund, technical needs which have been identified by industry. These needs would usually be met by applied research carried out at university centers. There are a number of reasons why SME feels that this program should be supported:

(1) By requiring cooperation as the basis for continuation, it represents a step toward reducing the adversary relationship between government and industry.

(2) The government role in the program is the appropriate one of facilitating private sector efforts. The government acts as a catalyst, but industry provides the financial support.

(3) The program provides recognition that productivity improvement is an important national goal.

(4) The program recognizes that technological innovation is important to the improvement of productivity.

(5) The program will act to strengthen the relationship between industry and the university community.

The Society of Manufacturing Engineers has an established history of contributory involvement in productivity, technological innovation, technology transfer, and cooperative technology in the many fields of manufacturing.[2] On the basis of this experience, the Society is highly supportive of both actions initiated by the Department of Commerce.

Accordingly, SME recommends the passage of satisfactory enabling legislation and encourages a strong national commitment to the new Cooperative Technology concept and organizational approach. SME feels that this form of Federal support of industrial technology advancement would reduce the adversial relationship that exists between government and industry, would provide a catalyst for action to improve productivity through technical innovation, and would strengthen the relationship between industry and the academic community.

## Appendix A.—Cooperative Technology and the Society of Manufacturing Engineers

The application of "cooperative technology activities" to assist or enhance specific industries or to generate new technology to meet specific national goals, does not represent a new Federal experience. It has been, and is being, effectively utilized in many programs within the Departments of Agriculture, Energy, Interior, Defense and Commerce, as well as other independent agencies.

The Manufacturing Technology Program within the Department of Defense is an example most familiar to SME. This program is specifically geared to insure economical and reliable production of defense materials through development of improved manufacturing processes, materials and equipment. SME's thrust is to broad-

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[1] Appendix A—"Cooperative Technology and the Society of Manufacturing Engineers" describes the Cooperative Technology Program as it relates to SME's sphere of interest and responsibility.

[2] Appendix B—"Productivity and the Society of Manufacturing Engineers" outlines SME's historical role and contributions to manufacturing productivity.

ly interpret and apply any major advances in manufacturing technology to the benefit of the private sector.

The National Science Foundation, through which much of the basic research expenditures of the government are channeled, is investing an increasing share of its resources in experimental programs for the application of fundamental science to industry problem-solving through cooperative technology mechanisms.

These programs have not been visibly oriented toward the productivity issue, however. Nor has the traditional governmental approach of investing in basic research, with the expectation that market forces alone will insure productive application, proven sufficient.

In its major role as a medium for technology transfer, the Society finds the greater need to be a new force to more rapidly accelerate the rate of implementation of existing technology in critical areas of the manufacturing sector.

A determination to effectively fill this critical void is clearly evidenced in planning efforts recently initiated by the Office of Science and Technology of the U.S. Department of Commerce. This is reflected in the stated objective of their Cooperative Technology Program: "* * * to spur production and accumulation of scientific and technical knowledge essential for industrial investment in the commercial development of critical technologies."

The mechanism for accomplishing this objective is fully compatible with the SME's 1978 position paper on productivity. The Cooperative Technology Program would:

(1) Increase the leverage of industrial funds by pooling resources to find solutions to common problems.

(2) Increase R. & D. funds to the critical level required for broad applicability to industry.

(3) Increase the capability of universities and technical institutes to support the effective utilization of technology in industry.

The planned mode of operation through Cooperative Technology Centers—industry-controlled but jointly-funded by industry and government—should insure work programs responsive to timely and real commercial needs. Properly executed, this program also has potential for a corrective contribution to an ailing national research and development environment.

Administration of the program, through an expanded function of the National Bureau of Standards, will provide a starting credibility, multidisciplinary perspective, and a focal point for integration with other related government programs.

The Department of Commerce has already initiated case studies in several technologies being considered for Cooperative Technology Programs. These preliminary studies are being carried out to test industry response, identify current needs and to make cost benefit determinations. These include, among others: (1) welding; (2) industrial coatings; (3) computer aided design; (4) powder metallurgy; (5) semiconductor fabrication; (6) flexible manufacturing; (7) corrosion protection; (8) radiation processing; and (9) composites. All of these are considered to be of significant interest to SME or SME-affiliated societies.

## CONCLUSIONS

The Cooperative Technology Program currently under development by the Department of Commerce is perceived as a viable action response to the expressed needs for Federal assistance in the innovation process. Successful implementation, with a stable long-term commitment to the plan concepts, should provide a significant new resource to combat the declining trend of national productivity. The proposed Cooperative Technology Program is fully compatible with, and should reinforce, the current programs and longer-range interests and strategies of the Society of Manufacturing Engineers.

This position recommendation carries with it an implied commitment for continuing application of the Society's resources to this common national purpose, in cooperation with this new medium of implementation. Support by SME is based on the conviction of urgency and need for constructive, as proposed to further investigative, action. The many impediments which must be minimized or eliminated to make this program truly effective, are fully recognized.

In the formative stages of the proposed Cooperative Technology Program, the Society will establish and maintain a close line of communication with the Office of Science and Technology. A diligent effort will be made to assist in their organizing efforts by offering technical expertise and the experience of our organization and membership in project planning and administration.

The short-term goal of this preliminary activity, to be controlled by the SME Technical Council, will be the selection of project alternatives related to the ad-

vanced manufacturing engineering needs which most satisfactorily meet federal, industry, and Society criteria.

## Appendix B.—Productivity and the Society of Manufacturing Engineers

### THE SOCIETY PROFILE

The Society of Manufacturing Engineers is a professional technical society dedicated to advancing manufacturing technology through the continuing education of manufacturing engineers and managers. The specific goal of the Society is "to advance scientific knowledge in the field of manufacturing engineering and to apply its resources to research, writing, publishing, and disseminating information."

The Society was founded in 1932 as the American Society of Tool Engineers. From 1960 to 1969, it was known as the American Society of Tool and Manufacturing Engineers; in January 1970 it became the Society of Manufacturing Engineers.

The changes in name reflect the evolution of the manufacturing engineering profession, and the growth and increasing sophistication of a technical society that has gained an international reputation for being the most knowledgeable and progressive voice in the field.

The principal on-going activities of the Society include:

*Conferences and expositions.*—Engineering conferences and expositions represent the most effective mediums for technology transfer. During 1978, 16 expositions and 32 conferences were held with total attendance exceeding 128,000.

*Educational programs.*—1978 educational activities included 65 three-day programs (clinics, seminars, workshops) devoted to a single subject, with technical paper presentations, problem-solving sessions and plant tours.

The Society also offers academic course materials on all aspects of manufacturing for individual study or group instruction. These include programmed learning courses, home study courses, correspondence courses, and video-tape training programs.

*Publications.*—The principal periodical of the Society is Manufacturing Engineering, published monthly and directed to the entire manufacturing community. A wide range of other publications deals more specifically with specialties within the broad spectrum of manufacturing engineering. These include the Tool and Manufacturing Engineers Handbook, Robotics Today, and the Manufacturing Data Series, consisting of 24 reference books on specific subjects within manufacturing engineering.

*Technical divisions.*—SME's function is to follow and assess the trends and developments in manufacturing; then to interpret, publish and distribute the information. To tap the technical talents of its 50,000 members, SME sponsors 13 Technical Divisions. These are subdivided into 70 technical areas and encompass all of the disciplines of engineering and management in manufacturing. More than 1,000 volunteers contribute their time and talent to provide the technical input for SME's educational programs.

*Associations of SME.*—To serve the widening technical interests of manufacturing engineers, SME also has created, and serves as headquarters for, several other associations or technical societies. These include the Robot Institute of America (RIA), the Association for Finishing Processes (AFP-SME), the Association of American CIRP Industrial Sponsors (AACIS), and the Computer and Automated Systems Association (CASA/SME).

*Research and educational grants.*—In addition to sponsoring more than 80 student chapters, covering more than 4,000 students at universities and colleges throughout the United States, the Society supports a program of research and educational grants. Its purpose is to promote the development of manufacturing engineering curricula in colleges and universities, to help upgrade the level of instruction where such programs already exist, and to attract an even higher caliber of students to the profession.

Since 1954, the Society has spent more than a half million dollars to sponsor research and provide capital equipment to educational institutions and to assist in the development of educational curricula.

*Standards.*—The Society works closely and continuously with the American National Standards Institute, the International Standards Organization, the American National Metric Council, and other national and international organizations. Its purpose is to help establish and maintain the highest possible standards in the field of manufacturing engineering for the benefit of industry and the profession.

Among the many other organizations with which SME is affiliated are the Association for Cooperation in Engineering, the Engineers Joint Council, the National

Council of Engineering Examiners, the American Automatic Controls Council, and the Federation of Materials Societies.

*Certification.*—Through its Manufacturing Engineering Certification Institute, the Society also certifies Manufacturing Engineers and Technologists for their technical expertise and knowledge acquired through on-the-job experience and informal education. Degreed personnel and registered professional engineers also may become Certified under this program, which was developed with the guidance and endorsement of industry.

THE SOCIETY AND PRODUCTIVITY

The constituency of the Society is primarily engineering professionals and technologists engaged in the manufacture of primary metal products, machinery, electric and electronic equipment, and miscellaneous manufactured products.

Historically, the Society has provided a forum for the expression of concern on various aspects of its members' job environments. Of special importance are the factors that limit growth and the achievement of personal goals. In the late 1960's, an awareness of a diminishing impact of their efforts and dedication to productivity improvement emerged from this forum. The causes, not then fully identified, were believed to be related to factors beyond either individual or management control.

The first responsive action to these concerns led to SME co-sponsorship with the National Science Foundation and the National Bureau of Standards of a "Manufacturing Productivity Conference" in October 1972. A primary result of this conference was the aggressive application of Society resources to the clarification of problems and the assessment of alternatives for constructive action. Some of the more significant events and actions which occurred as a result of this thrust are as follows:

Cooperation with the U.S. General Accounting Office in the development of information for their study on "Manufacturing Technology—A Changing Challenge to Improved Productivity." This was further extended to interpretation and dissemination of the study results and conclusions most relevant to the interests of the SME constituency.

Cooperation with the National Center for Productivity and Quality of Working Life in their continuing efforts to focus public awareness on productivity problems and the influence of federal policies on productivity.

Active participation in the Department of Defense sponsored Manufacturing Technology Advisory Group Conferences, recognizing that the prime determinant of the strength of our tri-services defense capabilities is highly dependent on the degree of advancement of manufacturing technology.

Active participation in the Air Force Integrated Computer-Aided Manufacturing Program aimed at the technology required to reduce the metalworking manufacturing process to total automation from initial design to finished product.

Active support of the robot industry and university institutes in pioneering efforts in promotion of advanced robotic technology. Since 1974, SME has co-sponsored an International Symposium on Industrial Robots on an annual basis.

These participating activities reflect a continuing SME effort to integrate and coordinate government, university, and private industry resources in the development and application of advanced manufacturing systems. They continue to demonstrate the fact that the basic technology, spawned in the massive atomic energy, space, and communication systems investments, are not approaching their potential for optimization and versatile automation of our factories.

A further consequence of this realization has been the internal restructuring of the Society's organization and programming emphasis. These changes have included the following:

The annual organization and implementation of a comprehensive conference and exposition on Computer Aided Design and Manufacturing (CAD/CAM) since 1972.

North American Industrial Robot Conference during the years when international conferences are held abroad.

The formation and incorporation of the Robot Institute of America to strengthen and support robot technology and its application in industry.

The organization of a new affiliated Computer and Automated Systems Association (CASA/SME) in 1976 to provide a forum for technical dialogue between a variety of engineering disciplines and to serve as an educational vehicle for its membership.

The formation and incorporation of an Association of American CIRP Industrial Sponsors to provide an independent medium for interchange of research needs and ideas, international technology transfer, and sponsorship of joint research on broad aspects of production engineering.

The organization and implementation of annual AUTOFACT Conferences and Expositions. These events recognize the ultimate need for integration of the many engineering technologies in robotics, computer applications, numerical control, and automation essential to attainment of the highest productivity goals. It addresses the future needs of an all-encompassing advanced manufacturing technology.

The formation of an affiliated Association for Finishing Processes (AFP/SME). This new organization was organized specifically to address emerging problems in development or adaptation of finishing systems to comply with volatile emission control, energy conservation, and toxic material handling regulations. It has provided the principal forum for technical information exchange since 1972 with major conferences and seminars on powder coating, radiation curing, water-borne and high solids coatings, and pretreatment technologies.

Stimulation, reinforcement and amplification of these accelerated efforts has been obtained by contracting for independent studies and surveys by established agencies. The first of these, entitled "The Manufacturing Engineer—Today and Tomorrow," was conducted by A. D. Little in July 1968. The principal motivation was the need for forecasting future educational needs, although its strongly signaled the technological changes we are now addressing. A recent update entitled "The Manufacturing Engineer—Past, Present and Future," conducted by Battelle Laboratories in May 1979, reaffirms and more clearly defines the technological changes occurring in manufacturing while emphasizing the need for educational adaptation.

The Delphi techniques for technological forecasting were applied by the University of Michigan in major studies of the direction of technological change in four areas of specific interest to the Society constituency. These include:

Manufacturing Systems and Material Removal—May 1977.
Manufacturing Management and Assembly—May 1978.
Quality Assurance—In Process.
Computer Aided Manufacturing—In Process.

CONCLUSIONS

This itemization of SME's expanding involvement in the promotion and application of advanced manufacturing technology reflects the body of thought now emerging as a national awareness. This decade of Society experience represents countless hours of valuable voluntary effort and contributions by engineers and technologists with personal dedication to professional and technological advancement.

It is significant that their independent rationalizations, as reflected in these activities, now converge with the observations and conclusions of industrial leaders, economists, and political planners.

Society efforts to stimulate innovation, to promote the application of advanced technology, and to break down communications barriers among engineers, industry, government, and educational institutions have made modest progress with limited financial resources. Even more significantly, the process has generated broad lines of communication, a credibility and competence base, and an understanding of the implementation problems to effectively contribute to an accelerated national productivity improvement program.

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EXXON RESEARCH & ENGINEERING CO.,
*Florham Park, N.J., July 6, 1979.*

Hon. ADLAI E. STEVENSON,
*U.S. Senate, Washington, D.C.*

DEAR SENATOR SETVENSON: Your letter of June 8, 1979 requested my comments on S. 1250, the National Technology Innovation Act of 1979 which you recently introduced in the Senate.

I certainly support the objectives of this legislation and believe it is a positive step toward improving the climate for technological innovation in the United States. I am, however, concerned about one aspect of S. 1250—the proposal to establish regional Centers for Industrial Technology. In my view, this concept, which relies on universities and nonprofit institutions to take the lead in strengthening the innovation process, is not the most effective means for achieving this objective.

The private sector, which is most effective in bringing new technology to the marketplace, must be involved in the fundamental research efforts undertaken by universities. I believe this can best be accomplished by building on existing relationships and does not require the establishment of specific Centers for Industrial Technology. In recent years, industry and academia have made significant strides in developing joint efforts that stimulate the innovation process. The Monsanto-Har-

vard agreement which Monte Throdahl described in testimony before your committee is an excellent example. Other companies, including Exxon, are exploring similar long-term cooperative agreements. Government policies could encourage the growth of such relationships through more favorable tax cooperative research programs at universities.

Sincerely,

ED DAVID.

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SMITH KLINE & FRENCH LABORATORIES,
*Philadelphia, Pa., July 6, 1979.*

Hon. ADLAI E. STEVENSON,
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: This will acknowledge receipt of a copy of the National Technology Innovation Act for 1979 (S. 1250) for review and comment.

I want to commend you for considering such a vital subject which is second only to our national security, in our opinion. Indeed, the subject of the industrial innovation is one of such urgency that certain actions would seem indicated immediately. These actions, it seems, could be taken now without the creation of the Office of Industrial Technology. We list some comments herewith; however, the list does not represent priorities since many of the suggestions are of equal importance and should be done together:

All government agencies should be required to review all regulations. Each should be justified in terms of its cost and benefit to society. Rather than proposing new government regulations, this study should focus on those things that we can do without.

Propose changes in federal law that would stimulate the rate of capital formation and encourage savings rather than consumption.

Consideration be given to a reduction of capital gains taxes and an assessment made of the impact of such a reduction on innovation.

Changes in the government procurement policy which would result in establishing standards that would stimulate industrial innovation.

Consideration of changes in tax laws and treasury regulations (Treasury Regulation 1.861-8) which stimulates U.S. multinational corporations to increase their investment abroad and, thus, outside of our national economy.

Studies should be made of the patent system and changes made that would encourage the availability of federal patents on an exclusive basis.

Consideration of ways to improve the viability and success of small companies directly involved in innovation and the production of new products.

An evaluation of different approaches to stimulating investment in R&D and the role that the government might play in directing federal resources to various high priority areas which would have long-term benefits to the scientific and technological community. Part of this analysis should be directed toward the establishment of federal priorities and technology.

Each recommendation made as part of a domestic policy review of innovation should be analyzed in detail and appropriate actions recommended.

Sincerely yours,

BRYCE DOUGLAS, Ph. D.,
*Vice President.*

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ALLIED CHEMICAL,
*Morristown, N.J., July 6, 1979.*

Hon. ADLAI E. STEVENSON,
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: This is in response to your memo dated June 8 on Legislation on Industrial Innovation.

Your comments and the suggested goals entered in the May 24, 1979 Congressional Record are praiseworthy. The problems are real and without remedies the price will be high. S. 1250 could be a significant step towards a solution. The direction of the suggested program could, however, follow any of a number of paths. We outside of government are all too aware that excellent intentions can become difficult to recognize after implementation.

The effectiveness of Centers affiliated with universities will depend on substantial changes in the latter's modes of operation and reward systems. In recent years there has been small but significant improvement in the willingness of universities

and industry to expand interactions crossing the academic-industrial line. By themselves, universities have not been major innovators in the last two or three decades. Along these lines I recommend two attached articles. One is by Mr. Peter F. Drucker, a well-known management consultant, and the other is an interview with Dr. Philip H. Abelson, the highly respected editor of Science. As a model of how to move towards solutions of problems they raise, one notes the recent activities by the National Science Foundation to support joint university-industry research programs. To solve the more basic problems, however, will take much greater efforts than the machinery of S. 1250 or the meritorious NSF programs.

A fundamental difficulty is that we are facing a new challenge, one to which you have referred in your comments in the Congressional Record. This is the qualitatively different competitive environment which is now appearing. There are nations, of which Japan is the leading example, where government, industry and universities are functioning in a partly competitive, partly collaborative mode. These countries can dominate critical markets throughout the world. The enclosed reprint, "What It Takes to Meet the Japanese Challenge," is worth reading. Again, it is the qualitative differences with our system which are of importance. That system has its origin in another era. Then individual organizations were sufficiently isolated to enable them to occupy profitable corners for long periods. Increasingly rapid communication and transportation make a continuation of such opportunities less likely in coming years.

A view of the world as a complex economic unit in which the entire United States economy is one subunit forces different perceptions and the possibilities of different solutions on us. Substantial changes will be necessary in the way many of our organizations function and interact. The National Technology and Innovation Act can be a worthy first step when associated with other, larger changes. It is these latter alterations which will be critical for its potential impact.

I am appreciative of the efforts that you and your colleagues have expended to try to take these steps. Many others will be needed in the future.

Sincerely yours,

W. WASSERMAN,
*Director, Corporate Research Center.*

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CHRYSLER CORP.,
*Detroit, Mich., July 6, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Thank you very much for sending us the copy of S. 1250 and your remarks entered in the Congressional Record of May 24. We are gratified to learn of your interest in the twin problems of declining innovation and productivity. Without question these unfavorable trends have to be reversed if the standard of living of U.S. citizens is to improve—or even remain constant.

We also agree that governmental action is required to solve the problem. The reason we think the government must act is because we think the government, in a large measure, is responsible for the problem. Of course, this was not deliberate on the part of anyone in government. To the contrary, the government had very different goals in mind when it established regulatory agencies like NHTSA, EPA, OSHA, and others. Nonetheless, the regulations which have poured out of these agencies have diverted both manpower and capital from the traditional quest for new products and improved processes, and the crush of regulation continues to worsen.

We support the goals of these agencies and have said so repeatedly. We take issue with them only when they begin to overregulate and their demands become unnecessarily costly, unproductive, time-consuming and, in many cases, conflicting. Here too we think we would agree with each other that most of these agencies are guilty of overregulation which is reducing productivity, causing unnecessary cost for consumers, and contributing to the rate of inflation.

Fundamentally, then, we seem to agree and we need only discuss the remedy for the problem we both recognize. Here at Chrysler we become a little less sure of the solution. We are not convinced that the establishment of an Office of Industrial Technology is necessarily the most efficient way to achieve the improvements we both want. We tend to think that a curtailment—in some cases a rollback—of regulations affecting U.S. industry would be more effective more quickly than a new office within the Department of Commerce. We estimate that 75% of our discretionary resources, R & D, capital, manpower, etc. are today being applied to meet

government regulations. This only leaves a small fraction of our formerly available resources to devote to innovation and productivity improvement. Giving us back some of our discretionary resources is by far the quickest and surest way to increase our ability to innovate and to improve productivity.

I hope these brief comments have been of some value to you and your staff. They only scratch the surface of a very complicated but very important subject. I would be more than happy to meet with you or your staff or to discuss the subject by telephone if you're interested. Please call on me if I can help.

Sincerely yours,

S. L. TERRY,
*Vice President,*
*Public Responsibility and Consumer Affairs.*

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DEERE & CO.,
*Moline, Ill., July 9, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology and Space,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: In endorse Senate Bill 1250, "National Techonolgy Innovation Act of 1979". It is conceived in recognition of a critical national need: stimulating technological innovation. Establishment of an Office of Industrial Technology and Centers for Industrial Technology are positive steps toward improving the coupling of the scientific capability of universities with the innovative capability of private industry. I am in complete agreement with the implication of the bill that the Centers shall be established "to the maximum extent feasible, on a self-sustaining basis."

The improved coupling of universities and industry sought by this legislation was one of the three priority goals formulated by the Department of Commerce Advisory Committee on Industrial Innovation. I had the honor to serve on the Federal Direct Support of Research and Development Subcommittee of this study.

The other priorities indentified dealt with increasing the incentives for individuals and corporations to invest more time, energy and resources in new innovative ventures and ensuring that the regulatory decision-making process is responsive to both the needs of society and the capability of society to afford the requisite costs.

As you pointed out in your Senate speech of 24 May 1979, the proposed legislation is not a comprehensive remedy for lagging industrial innovation which would include tax and regulatory considerations. I would hope that in the coming months legislation dealing with these specific aspects of the problems will be forthcoming.

You and the members of your Subcommittee on Science, Technology and Space are to be congratulated on the development of an excellent piece of legislation responsive to a complex national need. Its promotion of technology and science coupling when enacted will ultimately benefit our nation and its citizens by making our industrial sector more competitive in international trade.

Sincerely,

GORDON H. MILLAR.

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CHEVRON RESEARCH CO.,
*Richmond, Calif., July 9, 1979.*

Senator ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: This is in reply to your letter of June 8 concerning S. 1250, the National Technology Innovation Act of 1979.

First, I would like to compliment you on your understanding of the current economic picture in the United States. Such understanding, translated into effective leadership, is very much needed by all of us.

However, in my view S. 1250 is ill-advised. I come to this conclusion because I consider it unrealistic to expect Centers for Industrial Technology established under the Act in association with nonprofit institutions to make meaningful technical developments in a competitive world of free enterprise. Such centers would be coupled only loosely with the mainstream of world business and, lacking both a close coordination with the marketplace and a profit incentive, would be doomed to failure.

I would encourage you to attack the problem of stimulating U.S. technological innovation in another way; namely, try to foster an environment wherein government and industry work together as partners rather than as antagonists. For a number of years we have been methodically destroying the most innovative society that was ever assembled through a series of ill-advised government regulations, restrictions, and general disincentives placed on American industry. Some of the most vocal and effective proponents of this course of action have resided in the U.S. Congress.

Other nations, with Japan being an outstanding example, have strongly embraced the free enterprise profit motivated system and have marshalled the resources of government to aid and assist their national industries in maintaining a competitive position in world trade. These foreign governments do impose certain guidelines upon their industries in order to achieve national goals, but their uniform objective is to increase the competitive strength and capabilities of their industrial partners. Given such an environment in this country, American industry could maintain its competitive position in technological innovation working in conjunction with an adequately financed university system which could and would provide the necessary basic research foundation.

Fundamentally, I oppose S. 1250 because I do not believe it will work. There are things, however, that could be done to improve U.S. technological innovation along the lines I have outlined above. I appreciate being given an opportunity to comment on this important legislation.

Very truly yours,

J. R. THOMAS.

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CINCINNATI MILACRON,
*Cincinnati, Ohio, July 10, 1979.*

Senator ADLAI E. STEVENSON,
*Committee on Commerce, Science, and Transportation,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Thank your for inviting me to comment on your recently introduced bill, S. 1250, The National Technology Innovation Act of 1979. I am pleased to do so.

First concerning your remarks in introducing this bill, I find them most appropriate. They provide a very accurate description of the situation which this country faces today relative to international industrial competitiveness and its relation to technological innovation.

Concerning the bill itself, I find its provisions quite appropriate as first steps toward remedying the above situation. In fact, I feel that the steps proposed in this bill are *the* most necessary first steps to be taken. As I pointed out in my testimony to the Joint Economic Committee on June 5, 1979, concerning European activities in productivity enhancement, the heart of the European programs in support of industrial productivity improvement is joint government-university-industry cooperative activity in advancement and implementation of generic technology pertinent to industrial innovation and productivity, with particular emphasis on advanced manufacturing technology. This is also the key feature of your bill.

Further, the provisions of your bill are quite in harmony with the recommendation on R&D on generic technology which I authored during my participation in the work of the Advisory Subcommittee on Procurement and direct Federal Support of Research and Development during the domestic policy review of industrial innovation. That recommendation proposed establishment of Centers having the same general characteristics and functions as the Centers for Industrial Technology proposed in your bill.

In view of the above, I feel that enactment of your bill would provide the essential core needed for a successful developing program aimed at advancement of industrial productivity and innovation. Therefore I am highly supportive of the bill.

Should you wish me to amplify on any of the above points with you or your staff, I would be happy to do so.

Sincerely,

M. EUGENE MERCHANT,
*Director, Research Planning.*

NORTHROP CORP.,
*Los Angeles, Calif., July 10, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Northrop appreciates receipt for comment of the proposed National Technology Innovation Act of 1979, S. 1250.

Throughout its 40 year history, the Northrop Corporation emphasized technological innovation with respect to both its products and the techniques to develop and produce them, and we attribute the Corporation's growth primarily to this policy. Thus we agree that a boost to technological innovation on a national scale could greatly benefit the U.S. economy, national security, and the quality of life. While recognizing that innovation per se is a creative process which cannot be legislated, we do believe that your Technology Innovative Act can be expected to stimulate new ideas. Furthermore, we believe that the proposed Centers for Industrial Technology may foster an environment favorable to creative innovation through interdisciplinary interactions among the industrial and academic communities.

Northrop has also been requested to participate in the review of S. 1250 by the National Association of Manufacturers. Through that mechanism we expect to gain a better understanding of the several activities envisioned by the Act and the contribute constructively thereto.

Sincerely,

D. A. HICKS.

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CATERPILLAR TRACTOR CO.,
*Peoria, Ill., July 10, 1979.*

Senator ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Thank you very much for contacting Caterpillar Tractor Co. in regard to S. 1250, to promote innovation in the U.S. We certainly agree with your purposes as it is essential that this country compete effectively with the rest of the world.

Caterpillar participates in the Industrial Research Institute, Inc., (IRI), Membership of which includes the technical organizations of a large number of U.S. companies. IRI has been and is active in developing the consenses of these diverse organizations on a number of items related to the subject matter of S. 1250. For example, IRI has issued position statements on "Licensing of Technology" and "Recognition and Awards for Industrial Innovation". Recently the Institute has surveyed its members on "External Environment and Technology Innovation" and "Impact of Regulation on Innovation". I feel that contact with this group might provide you with quite a broad industry view of the subject. The person to contact is: Dr. Jason M. Salsbury, President, Industrial Research Institute, Inc., 100 Park Avenue, Suite 2209, New York, New York 10017, Ph. 212/683-7626.

As noted above, we agree with the need for increasing industrial innovation in the U.S. If a national program is to attempt to improve this situation we agree with the concept that its Review Panel should contain a majority from business and industry. Without this type guidance the yield from university and other non-profit research centers is likely to be small indeed.

The areas of investigation outlined in S. 1250 such as identification of technological needs, capital and resource requirements and active or inactive plans to satisfy the needs already exist in many cases in industry in some form. What the "Center" will have to learn in some cases industry already knows; again a need for industrial input.

Finally, S. 1250 advocates joint government-industry sponsorship of program. It should also be noted that relief from antitrust provisions that would allow industry to cooperate on research on generic subjects could also expand this needed work and more effectively use U.S. resources.

In the interest of saving time, I have discussed S. 1250 with IRI so that they may comment and be better able to respond if you contact them. Thank you for seeking our views on this important legislation.

Yours truly,

T. H. FONES,
*Director of Research.*

MONSANTO CO.,
*St. Louis, Mo., July 10, 1979.*

Mr. MIKE CRISP,
*Minority Staff, Senate Committee on Commerce, Science, and Transportation, Dirksen Senate Office Building, Washington, D.C.*

DEAR MR. CRISP: I am pleased to be able to provide assistance to you and your staff in preparation of S. 1250. By encouraging industrial-academic collaboration, you are taking advantage of some of this nation's greatest resources, and taking a key first step toward establishing our innovative excellence.

In answer to the specific questions presented in Senator Schmitt's letter to me of June 29, 1979:

1. Joint collaboration between two competing companies may present antitrust questions in regard to any exclusive rights that they may receive under S. 1250. Competitors contributing to the same joint research project should be permitted to have an arrangement between themselves as to who shall be entitled to the exclusives of inventions relative thereto or any parts of such exclusives. That type of arrangement should be permissible and language to that effect should be inserted into S. 1250.

2. A major incentive already provided by S. 1250 is the ability of the directors of the centers to maintain information regarding the projects as confidential and not subject to the Freedom of Information Act.

The bill would be greatly strengthened, however, if exclusive licensing was assured for companies who participate in research at the centers. As I said in my testimony, the success of the Centers absolutely depends on granting exclusive licenses—with appropriate "march-in" rights. Specifically, I would suggest that "and be limited to the time necessary to allow for recompment of investment by the licensee" be deleted from 6(e)(4). Administering such a provision would be extremely difficult and the licensee would face great uncertainty.

It would be helpful to turn around 6(e)(3) to put emphasis on exclusivity rather than nonexclusivity.

3. Although my written testimony supported a slightly different funding pattern than that suggested in the bill, the amounts were not greatly different. As proposed, the funds would have to be used in concentrated doses. You can't expect that level of funding to reap benefits if it is scattered across a broad range of technology. Careful direction is key to the whole purpose and outcome of this act.

My written testimony also suggested that large companies pay 50 percent of the cost of a joint project, with smaller companies paying only 25 percent. This would help the government funds go further without decreasing the effectiveness of the bill.

The R&D budget at Monsanto is $170.6 million for 1979.

4. Clearly the centers should have the right to decide whether a company should have exclusive licensing on a project. Since the centers will be responsible for negotiating with companies to institute projects, they should be in a position to offer tradeoffs. It is important that the centers to able to strike a deal from the beginning which allows for settlement of patent rights. Besides, if the decision were to be placed in the Commerce Department, additional manpower would be required both within the center and within the DOC to provide the information to allow the government officials to make the decision.

The patent provisions of the bill are appropriate for the centers but the degree of exclusivity should be increased as noted above.

5. The stage at which the private sector should take over a project for commercialization will by necessity vary with the particular project, and would have to be worked out between the center and the sponsor. In some cases it might be appropriate for a center to step out at an early stage, such as in the case of an industry where production equipment already exists, and the product itself is the only innovation. In other cases, i.e. a new company without a production line and equipment, the center might be needed all the way to the test marketing stage before a company is able and willing to make the necessary commitment.

6. The Office of Industrial Technology will probably have enough to do simply administering the major provisions of S. 1250 without undertaking a study of other federal regulations and laws. Besides, there are plenty of people willing to step forward and identify the burdensome regulations: we don't need to create another bureaucracy to do that.

Thank you again for allowing me to participate in shaping S. 1250. If I can be of further assistance in this matter, please let me know.

Sincerely,

MONTE THRODAHL.

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UNIVERSITY OF SOUTHERN MAINE,
*Portland, Maine, July 10, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: We are writing in response to your letter of June 8, 1979 in which you solicit our comments on S. 1250, the "National Technology Innovation Act of 1979."

The New Enterprise Institute (NEI) at the University of Southern Maine for the last three years has been providing management and technical assistance to new and existing Maine businesses in an effort to achieve a long-lasting impact on the state's economy. It has been our experience that technologically oriented and innovative companies have a disproportionate positive effect on Maine's economy and, as a consequence, we believe publicly-funded business assistance programs should concentrate on this sector. These programs frequently provide the catalytic support necessary to stimulate the launching of a new product line, the introduction of a new manufacturing technique, or the development of a different marketing strategy, for example.

NEI has been designated both an EDA Technical Assistance Center and an SBA Small Business Development Center and, having operated both of these programs for two years, we are convinced that the business-university partnership can work. We think it is important, however, that the Office of Industrial Technology permit program flexibility. What works, or is appropriate in one region, may not work well in another in light of social, demographic, and economic differences.

We believe S. 1250 can be an effective measure to help reduce the current national trade imbalance by stimulating the growth and development of profitable, innovative companies through this cooperative approach. We would appreciate being kept informed of the proposed act's progress.

Sincerely,

STEPHEN P. HYDE.

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BELL LABORATORIES,
*Murray Hill, N.J., July 11, 1979.*

Senator ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: This is in response to your request for comments on S. 1250.

I believe that S. 1250 is a step forward toward solution of an important national problem. The rate and quality of industrial innovation are of concern because they are so essential to economic growth, productivity, and social progress. Considerable evidence indicates that the U.S. is now falling well below its potential in this regard, and that there has been a significant decline in recent years. In several continuing studies conducted by the National Academy of Engineering, under my Chairmanship, the causes for our failure to live up to our national potential have been studied in some depth. These point to a variety of government policies as major factors leading to the present situation.

It is important to realize that the root cause has *not* been underfunding of R&D by industry. Indeed, NSF figures show that there has been a continuing rise (in constant dollars) in industry-funded R&D, and that it now constitutes approximately half of all U.S. R&D. Also, the cause is not to be found in any change in government R&D spending patterns, as little of this has traditionally been directed toward commercial applications. Thus in looking for a "cure" for the perceived problem, it is apparent that measures designed only to increase R&D for industrial applications (through stimulation of industry funding of R&D, or through government funding of R&D with industrial uses as its purpose) can hardly be the most significant step we could take, as there is ample evidence that R&D funds are now sufficient. There are more fundamental causes for the problem, which must be dealt with.

Most of the costs of innovation are beyond the R&D stage; R&D is necessary for innovation, but far from sufficient. In our NAE studies, it has been clearly found that the most important reasons for the change in rate and quality of innovation are the uncertainties, costs, and time-delays introduced into the innovation process by regulation; the uncertainties and costs for innovation that derive from high inflation rates, high interest rates, and tax policies that do not have the encouragement of innovation as an objective; antitrust policies; and certain aspects of patent policy.

Accordingly, I would welcome the creation by S. 1250 of an Office with responsibility for the analysis of policies and conditions that affect industrial innovation. The closest approach in the government to analytical work of that kind is, at present, in the NSF, in the STIA Directorate, but this has never been intended to be comprehensive or complete, but rather, it supports scholarly work in this important policy area. Section 5(c) spells out quite satisfactorily what such an Office could do, and I would see this as an important policy (and legislative) aid, one that is now lacking. I would feel, however, that S. 1250 needs to clarify the relationship between this Office and existing functions in the Commerce Department, as there is an obvious need to find a good fit between them and to avoid redundancy.

Sections 6 and 7 of S. 1250 deal with Centers for Industrial Technology and with grants and cooperative agreements in support of them. I have a mixed reaction to this. On the negative side there are two things to be said. One is that the problem is not primarily R&D, as I have stated above, and this proposal could be said to be addressing itself to the part of the innovation process least in need of attention, i.e. R&D. The other is that the government has never proven itself capable of successful intervention in commercial markets and innovation for them, and it is therefore unlikely to exhibit the needed ability to set proper priorities for the work of the Centers and the Cooperative Agreements, being more likely than not to respond merely to skillfully prepared and presented proposals that do more to further some particular institution's self-interest than to meet any real national need. In this connection, it would be important for the Committee to hear from the users of the present university-based centers, on innovations they have made based on the work of such centers, and not only from the centers themselves.

On the positive side there are also two points I would make. One is that the universities constitute a tremendous present and potential resource to industry and are not as fully coupled to industry as they might be (and as they once were, before the years in which government funding of university research on an unprecedented scale greatly reduced the interest of universities in research related to industry). There are some large areas, important to industry and to national progress in such vital matters as productivity, which have received little attention in the universities, and attention to these through federal funding could be quite important. The other point I would make is that there are a number of industrial segments in the U.S.—those with a low "R&D-intensiveness"—which badly need a boost if they are to modernize and become competitive in world markets, and there may be need for a federal role in this.

I come out then moderately on the positive side with respect to the Centers, but with a strong feeling that their success or lack thereof will depend critically upon their choice of projects to support. The kind I think they should support is indicated by what I have said above. One way to increase the likelihood that the Centers will do really useful work—i.e., have a measurable positive effect on innovation—is to put considerable emphasis on the composition and powers of the Review Panel, and Section 9 does just that, for the most part. I would go even farther, and let the Review Panel make the final decision on projects to be supported.

It is not entirely obvious to me that "Centers" need to be created, as there are already well-established receptors for federal and industry funds in the universities, and the main point is simply to encourage research of a desirable kind. It would not be wise to limit research in any important research area to a single "Center" or university, as it might well be that several university groups could offer relevant research capability.

There are some other specific points in S. 1250 calling for comment:

(1) The preference expressed for nonexclusive licensing (Section 6(e)(3)) could well defeat the purposes of the bill. Industry would be most unlikely to commercialize results on the basis of a nonexclusive license.

(2) Attention needs to be given to the antitrust implications of projects involving several companies in one industry. In the absence of a specific statement in the bill on this, many companies would not risk a possible Department of Justice or Federal Trade Commission suit by engaging in cooperative activities.

(3) I doubt very much that the proposed Centers would be able to develop curricula and offer instruction in invention, entrepreneurship and innovation, and I would delete Section 6(b)(4). The student training would undoubtedly come from participation in projects, not from curricula and instruction.

Finally I would point out that a very promising program to investigate ways the federal government could stimulate innovation was launched several years ago, but has been allowed to languish for lack of funds and attention. This was the Experimental Technology Incentives Program, under Dr. Jordan Lewis, at the National Bureau of Standards (not to be confused with a companion program at NSF, called ERDIP, which never got off the ground). It is unfortunate that there has never been adequate utilization of the ETIP capability and findings.

I hope these brief comments will be of some use to you, and would be glad to elaborate on them if that would be helpful.

Sincerely yours,

BRUCE HANNAY.

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MARTIN MARIETTA AEROSPACE,
*Bethesda, Md., July 12, 1979.*

Hon. ADLAI E. STEVENSON,
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Your memorandum dated June 8, 1979 on the subject of legislation on industrial innovation and the accompanying bill S. 1250, the National Technology Innovation Act of 1979, have been read with a great deal of interest. I am encouraged by your involvement in the matter of improving productivity and would like to offer the following comments for your consideration.

Generally speaking, I believe that carrying out the provisions of S. 1250 may not have the beneficial effect on the level of industrial innovation in this country that you are seeking. Bills which, however well-intentioned, create still more governmental overview of technology may only further suppress the incentives and freedom of action which are so necessary to innovation. Better by far to concentrate on the reverse, as suggested by the Commerce studies of the influences of tax and regulatory policy.

I believe additional consideration should be given to the implication that there is a necessity to stimulate collaboration between universities and industry. There are today many joint research and development programs in progress and considerable mutual subcontracting of high technology items. Industry makes use of specialized university test facilities and personnel and frequently calls upon university faculty for consulting services. Also there is a constant movement of technical personnel from one regime to the other. It is important that legislation not merely generate grants supporting the activities that would have taken place in any event. A deterrent to this concern might be the reluctance in many cases to accept the inevitable restrictions attendant to government participation.

Another concern, although not a major consideration of the bill, is contained in the words "minimizing cost of duplicative research." It would tend to perpetrate the belief that there is something unconscionable about more than one person or one organization seeking to accomplish the same thing at the same time. Often, two efforts are not exactly alike and what may appear to be duplicative efforts may even have entirely different goals. Even if the goals are identical, some efforts will succeed, some will not. Moreover, some duplication is absolutely essential to competition, and without competition we would never have the chance to select the better solution.

Your sincere concern about the current state of American industrial technology is deeply appreciated. One can only wish you every success in finding the means to bring about lasting improvements. To that end I hope the foregoing discussion will serve a useful purpose. In any event I certainly thank you for the opportunity to comment on the proposed legislation.

Sincerely yours,

LAURENCE J. ADAMS, *President.*

THE BENDIX CORP.,
*Southfield, Mich., July 13, 1979.*

Mr. STEVEN FLAJSER,
*Committee on Commerce, Science, and Transportation,*
*U.S. Senate, Washington, D.C.*

DEAR MR. FLAJSER: It was a pleasure talking with you concerning the proposed Legislation on Industrial Innovation (S. 1250). Below is a recapitulation of those comments which may be of use to you. For your perspective, my responsibilities at Bendix are for technology across the company. Bendix is a manufacturer of equipment for the automotive, aerospace/electronics, industrial, and shelter industries.

I strongly support the notion that we need to refresh our national purpose with respect to innovation in products and manufacturing processes. I believe there are many good ideas embodied in the proposed legislation. Here are a few suggestions which may help clarify or improve this bill:

1. Our telephone conversation made it clear that Section 7 (Grants and Cooperative Agreements) is intended to apply to the Centers for Industrial Technology established in Section 6. This is not evident from reading the bill.

2. If Section 7 is intended presently to apply to the centers, then additional provisions are needed to make similar grant and cooperative agreement money available to good ideas which do not occur at the centers. There are many instances of small companies, individual university professors, or other unpredictable circumstances where worthwhile ideas originate but cannot easily be handled at the centers. I believe it is in our national interest to have a balanced program which provides: (a) Continuity of effort in certain fields, at the centers. (b) Opportunistic support for individual meritorious ideas wherever they may occur.

3. As I read Section 10 (Authorization of Appropriations)—and I am an amateur at such reading—funds are provided for the establishment of the centers, and for administrative and planning studies. It is not clear where any grant monies are provided to implement Section 7, especially if any of Section 7 is to apply outside of the centers. I would especially recommend that the legislation establish a balance between monies for the centers, and monies for the projects outside the centers.

4. The grant program, as presently envisioned, would fade out as the centers become self-supporting. Since this may be a legitimate objective in the longer term, I believe it is important to retain some form of matching support for the centers or for individual projects for a considerable period of time. In particular, it would be demotivating to reduce governmental support for a center just because it had gotten some industrial support. Some form of matching grant should be retained as a stimulus, perhaps with a decreasing ratio.

Good ideas are unpredictable and do not occur where organization charts and legislation say they should. It is critically important that an attempt to stimulate technical innovation recognize this, and be prepared to support innovation wherever and whenever it occurs.

Yours very truly,

JOHN W. WEIL.

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STATEMENT OF PINNY COOKE, ASSEMBLYWOMAN, 132D DISTRICT, NEW YORK

I welcome this opportunity to express my views on S. 1250, the National Technology Innovation Act of 1979. We in New York share your deep concern over the decline in our nation's technological leadership. Among the states, New York has suffered disproportionately in the loss of jobs, businesses, and productivity. Faced with double-digit inflation and an impending economic slowdown, our State has not yet fully recovered from the recession of 1974–75. It is, therefore, with a sense of urgency that I make the following observations on your legislation.

First, you are to be commended for recognizing the full dimensions of the loss of technological leadership to other countries. The federal government must take the lead in assessing the adequacy of current capital, technical and other resources for raising productivity, stabilizing the dollar at home and abroad, and achieving economic prosperity. It is equally important that measures to stimulate technological innovation be coordinated nationally. Lacking such coordination, duplicative or conflicting policies in the public sector will be the inevitable result.

Federal leadership in this area should not be achieved, however, without the full participation of state governments. In my view, state government has a vital role to play in stimulating industrial technology. State actions affect the creation of skilled jobs, the rate of economic growth and long-term regional development. Through their tax and finance policies, state governments may decisively shape the rate of

corporate investment, including funds allocated for research and development. Similarly, the level of support by state government for research purposes at institutions of higher learning can have a major impact on the rate of discoveries and innovations having ultimate commercial value. State regulatory and procurement practices also affect the rate of technology innovation, especially that of small, high technology companies which have less "slack" to withstand adverse economic conditions. In recognition of this responsibility, the New York State Science and Technology Foundation has been given the mission of encouraging the development of high technology industries in the State.

During the 1979 Legislative Session, Assembly Minority Leader James L. Emery and I were successful in obtaining an appropriation for a feasibility study by the Science and Technology Foundation for a High Technology Park in Monroe County. Monroe County and the Rochester, New York area have eight institutions of higher learning, including such schools as the University of Rochester, Rochester Institute of Technology, Monroe Community College and the State Universities at Brockport and Geneseo. In addition, Rochester is the base of such international corporations as Kodak, Xerox, Bausch and Lomb, General Railway Signal, Sybron and Gleason Works, as well as many other nationally known corporations too numerous to mention. This appropriation is the first project to be directly funded by the Legislature under the Foundation's new mission. It is important that State initiatives such as these be expanded and strenghtened by a "National Technology Innovation Act". As presently drafted, S. 1250 makes no apparent provision for State participation and would instead involve the federal government, private industry, and universities in the formation of Centers for Industrial Technology.

While I believe the cooperative "institutional approach" is sound, there is much to lose and little to gain by not making state government one of the institutional partners. In fact, some states, including New York, already embrace the institutional partnership approach that S. 1250 appears to advocate. The experience of these states could prove to be invaluable in making a national technology innovation act workable and effective.

I urge you to include the New York State Science and Technology Foundation and similar state-level bodies as possible sites for the proposed Centers for Industrial Technology and as recipients of planning funds. The Foundation now works with the private sector and other State economic development agencies in such areas as financial support, attraction of federal research and development funds, development of industrial parks for high technology firms, and the identification and commercialization of viable new products. The overall result is an improved environment for the attraction and growth of high technology industries in New York State.

I would also urge you to consider adding representatives from state government to the Industrial Technology Review Panel. S. 1250 presently provides for Panel members to be drawn from the disciplines and fields dealing with technology, labor and industrial innovation, a majority of whom would come from industry and business. It is imperative that those in state governments have direct input into the oversight role this Panel could be expected to exercise.

Finally, I believe that the Empire State is uniquely qualified to participate in a national program such as you propose. The neglect of research and development application to new product development is partially responsible for this country's chronic trade deficits, high inflation and unemployment rates and present currency difficulties. New York State is in a position to readily overcome these problems and its own chronic economic difficulties since it is well endowed with the two essential elements necessary for the development of new products and jobs. These are a vigorous and ongoing scientific establishment and a business community with the experience and resources to finance new ventures and industrial expansion. New York State contains about 10 percent of the nation's scientists and engineers and, of course, is the financial capitol of the world. In the past, the innovation of the former and the exploitation of new discoveries by the latter has been accomplished largely by chance. Badly needed now are the means for bringing these elements together in a way that would result in a rapid and more orderly translation of the fruits of an innovative scientific establishment into new and better product development, and to the establishment of additional jobs and job opportunities in the private sector.

Officials estimate that New York State is now being shortchanged by $1 billion in the amount of federal research and development monies it receives. Furthermore, New York's share of Research and Development funds has been declining over the past 13 years. In 1976 New York received only 5 percent of federal Research and Development money. Based on our State's percent of population, personal income, federal taxes paid, and numbers of scientists and engineers, we should be able to

attract twice that amount—10 percent. This figure is conservative considering the fact that California receives five times as much Research and Development money as New York, yet pays much less in federal taxes. Increasing the amount of federal Research and Development funds in New York would make a significant improvement in the State's employment situation, especially since high technology jobs have a multiplier effect on the creation of jobs. I therefore see a very active participation of New York State in the S. 1250 program.

In closing, I wish to impart once again the necessity and vital importance of full state participation in cooperation with the Federal government in the National Technology Innovation Act of 1979. I strongly believe, for the reasons stated earlier, that state participation in this program is imperative to its success.

I wish to extend by sincere appreciation to you, Mr. Chairman, and the members of this committee for the opportunity to be here today and to share my information with you on this very important subject. I do indeed love New York State.

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GRUMMAN CORP.,
*Bethpage, N.Y., July 16, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Thank you for inviting my comments on your proposed National Technology Act. I have some strong convictions on the issues involved and appreciate this opportunity to offer them for your consideration.

I support the intent of your bill wholeheartedly. The problems identified in your statement to the Senate are real and urgent. Legislation is needed.

However, I am skeptical of the specific remedies you propose. The bill would establish another agency, some number of centers, new planning grants, detailed reporting requirements and a review panel. It is not clear how these activities are to be coordinated with the established programs of other agencies. Nor is it clear that the proposed legislation would rationalize or make more efficient the many government actions which occur in this general area.

America's technological leadership is declining not for lack of new ideas but largely because our tax laws make technology an unattractive investment. For example, Grumman cannot justify the installation of solar energy systems because the cost of heating oil is deductible as a business expense, but the cost of solar systems must be treated as a capital investment and amortized over a number of years.

Chairman William Miller has proposed a simple tax measure that he believes would have an immediate and powerful effect: allow one-year depreciation for energy and environmental investments, five-year depreciation for new factory or laboratory equipment and ten-year depreciation for new plant investments. Perhaps the formula could be improved, but the approach is exactly right, in my view.

It seems obvious that the American people are impatient with government and not receptive to proposals that would create more federal apparatus. I believe legislation to eliminate the impediments to technological progress imposed by government would find a greater constituency than would legislation to create more government.

If I can provide any further information as you and your committee consider this crucial issue, I should be very glad to hear from you again.

Very truly yours,

JOSEPH G. GAVIN, Jr.,
*President.*

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ROCKWELL INTERNATIONAL,
ELECTRONIC DEVICES DIVISION,
*Anaheim, Calif., July 17, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space,*
*U.S. Senate, Washington, D.C.*

DEAR CHAIRMAN STEVENSON: Rockwell's Microelectronics Business has been active in working with Members of Mr. Baruch's staff in assessing a potential Cooperative Technology Program for the Semiconductor Industry. We thus read your proposed S. 1250 with this in mind.

Our attached comments on S. 1250 are to be taken in the light of the discussions at a Semiconductor Cooperative Technology meeting in mid June which was sponsored by the Commerce Department and the Semiconductor Industry Association. We have serious concern about the threat of concerted, government sponsored semiconductor technology advancement going on in other countries, especially Japan, Germany, France and Great Britain. Since we experience regularly what appears to be uncoordinated and unsympathetic responses to this threat by many elements and branches of the U.S. Government, we are pleased that the programs described in S. 1250 are positive. I hope the attached comments are helpful and constructive.

Sincerely,

R. E. ANSLOW,
*Director, Business Development.*

Enclosure.

ITEMS AND COMMENTS

Page 6: (3) You refer to "improving" regulatory actions. We hope you mean providing for "balanced" regulation, not just more regulation. By "balanced" we mean that the regulations consider the social, economic and national competitiveness factors as well as the specific regulation which, at present, does not appear balanced or coordinated with other regulations.

Pages 6 to 12: The pages describing the Centers do not address these issues of funding from industry and business:

How will industry help fund the start up of the Centers when there are no products or ideas to license or collect fees upon?

Will special benefits such as exclusive licenses, or earlier licenses than awarded to competition, go to companies who do fund the Centers? What about those who chose not to contribute, or who cannot afford to? What about U.S. subsidiaries of foreign firms?

Does the above point have anti-trust, or FTC implications?

Note: We have held discussions on these issues in the Planning meetings for a possible Semiconductor Cooperative Technology Program. There was no resolution as of this writing.

Overall, we have a concern that the Office of Industrial Technology will become another bureaucracy that becomes self serving, and we recommend that you and your staff do whatever is possible to minimize this possibility.

The National Technology Innovation Act offers us the opportunity to wage the growing trade and technology war on terms closer to those of our economic adversaries overseas. We trust you will take our comments with this in mind with the results being an Act that will achieve this for U.S. industry.

Page 2: (3) This could infer that many, even most scientific advances occur in univsersities and Government Laboratories. While many worthwile innovations do occur in those institutions, the discoveries and advances in many fields occur in industrial laboratories. Our field of semiconductors is a key example where industrial innovation, at least in the U.S., overshadows developments in Universities and the Government (except in certain aspects such as measurement where the National Bureau of Standards is a leader).

(4) The bill states we "may be lagging". We believe any studies you care to conduct will show that we are lagging.

(6) You state that the various Government influences can have significant impacts. How about further stating that because these are largely uncoordinated influences, the impact probably is, in the overall, a negative or detrimental one when considering technical innovation.

(7) You might strengthen this point by suggesting that enhanced technological innovation can improve our National Position per Item (2) above. "Commercial and public purposes" sound bland.

Pages 4 and 5: It isn't stated here, but what if the Director and his staff found that the actions and activities of other Government entities, such as OSHA, the ICC, NTSB, the tax laws, the office of Export Regulation, etc. were, either individually, or when taken together, significant inhibitors of innovation. Is it intended that such observations would be made in the Director's report (Paragraph 'd') and recommendations made that would assist in improving the climate or economics of technical innovation?

PHILLIPS PETROLEUM CO.,
*Bartlesville, Okla., July 27, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: I appreciate the opportunity extended by you to review and comment on your bill S. 1250. It is indeed important that we find a way in which the United States can recover the initiative in technology and industrial innovation.

The concept incorporated in S. 1250 does not, in my opinion, approach the problem from the right direction. One important deterrent to innovation in our country has been the increased tendency for the federal government and its agencies to try to do all things for all people. Often technical control and evaluations have been made by persons having no personal knowledge of the practical aspects at issue. That has resulted in private industry having to spend an inordinate amount of its technical manpower trying to prove to the overseer or regulator the validity of information not generally known in government.

The illogical application of the Freedom of Information Act also increases the difficulty in permitting private industry to safely present its proprietary technical information through a governmental policy.

Private industry has been and continues to be capable of evaluating the needs of people and of our nation. Growth of our industries has not just happened. Americans have been innovative. They have recognized problems and developed solutions. Based on fundamental economics of the profit system our industries flourished.

Bill S. 1250 would, as has so often been the case over the past 25 years, interject yet another federal agency into the picture. Siphoning off monies which could otherwise be used by industry to make its own evaluations and develop solutions for problems, the federal government would impose another layer of bureauracy to the already heavy burden of federal government carried by the taxpayers.

We have been waiting with hopeful anticipation the results of the President's Domestic Policy Review of Industrial Innovation. Our representative in that review reported that the broad spectra of people and backgrounds involved in that study provided some excellent possibilities for improving innovation.

I would prefer that Congress take a look at the outcome of that study and see what private industry can do for its country rather than adding another governmental "aid".

Thank you very much for permitting me to review this matter.

Sincerely yours,

I. W. DAVISON.

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STATEMENT OF WAYNE S. BROWN, PH. D., PROFESSOR, MECHANICAL ENGINEERING, DIRECTOR, UTAH INNOVATION CENTER, UNIVERSITY OF UTAH

This presentation will discuss utilization of universities as a resource to achieve technical innovation. The desirable effects of technical innovation on the U.S. economy and our lifestyle are evident. This presentation begins with the assumptions that high technology business enterprise is an asset to our country and that the ability of inventor-entrepreneurs to establish and develop new technology-based firms is a critical component of technological innvoation and, indeed, of the free enterprise system.

The roles of individual inventors and small businesses, as highly productive sources of technological innovation, have been well documented.

The 1978 report of the Joint Senate and House Hearings on Small Business and Innovation, page 8 says, "Simply stated, an individual who has made a discovery wants to reap as many of the benefits of commercialization as possible, and the vehicle for maximizing these benefits is a new business." [1]

The report cites, on page 6, an important American Electronics Association study saying, "The results of the study of this technology industry likewise reflect a similar pattern: The new and small enterprises with new innovative products demonstrated higher rates of growth, job creation and other contributions to the U.S. economy in terms of overall growth, taxes paid and export sales." [2] It is important to note that this study focuses on the contribution of start-ups within an industry which is in itself regarded as a model of innovation.

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[1] Senate Small Business S. Rept. 95-1413, Oct. 11, 1978, p. 8. U.S. Government Printing Office No. 37-152 O.

[2] Ibid., p. 6.

The Charpie Report, pages 13 and 14, makes the following statements, . . ."In our over-all deliberations, we came to some general conclusions about the kind of total environment that seems to encourage the creation of new technological enterprises. Included in this environment are: . . . Technologically oriented universities, located in an area with a business climate that encourages staff, faculty and students to study and themselves generate technological ventures." [3]

Universities played a significant role in the establishment of the high technology business centers along Route 128 near Boston and in Santa Clara County in California. The great universities in these areas provided an innovative research atmosphere and trained engineers, scientists and managers capable of creating new companies built around emerging technologies. Indeed, many of the technical concepts which made the businesses possible originated in the research laboratories of the universities. Frederick Terman, who served successively as Chairman of Electrical Engineering, Dean of Engineering and Provost of Stanford University, deserves much of the credit for establishing an environment conducive to technical innovation and entrepreneurship around Stanford. By providing encouragement and limited assistance from the University to firms such as Hewlitt and Packard, and Varian Associates he helped establish the nucleus for what was to become Silicon Valley. As investors achieved success from investments in such businesses, financing became available for other new ventures. Capable people were attracted to the area, and today a climate for high technology business exists that is unequaled in the entire world.

Observing the impressive array of business activity which has sprung up over the past twenty years near Stanford has convinced me that universities can indeed play an important role in establishing a high technology business climate. What is amazing to me is that we have numerous examples of outstanding universities in our country where very little technical business activity has developed. Stimulation of other centers of technological business enterprise such as that around Stanford University should be encouraged. The National Science Foundation-sponsored Innovation Center Experiment is an approach to fostering new enterprise formation which has particular merit.

The newest of the four National Science Foundation-sponsored Innovation Centers is located at the University of Utah. As Director of that center, I have emphasized new business start-ups with faculty, students, and others as our primary mission. Prior to the establishment of the center, the College of Engineering had several successful spin-offs which have resulted in profitable companies employing significant numbers of people in the Salt Lake City area.

Kenway, Inc. was founded in 1964 by Ken Richins and myself as a contract engineering firm. As time progressed, Ken Richins gave up his teaching duties at the University and devoted his full-time efforts to building a company which now dominates the market for high-rise automated warehouse systems. The firm which employs 750 people with annual sales in excess of $70 million was recently purchased by the Eaton Corporation.

Terra Tek, Inc. grew out of a rock mechanics research program which I directed at the University of Utah. Together with colleagues from other universities, I established this company in 1969. The company specializes in performing tests for the oil and gas industry, the geothermal industry and government agencies to determine the properties of rock samples under the high pressures encountered deep in the earth. The capabilities of this laboratory are unmatched in the world.

The Drilling Research Laboratory, a wholly-owned subsidiary of Terra Tek, operates a unique facility in which a full-scale oil well drilling rig performs drilling tests within a large pressure vessel. The apparatus can simulate the field conditions encountered in an oil well 20,000 feet deep. Terra Tek has annual sales of $6 million and employs 140 people.

Native Plants, Inc., a partially-owned subsidiary of Terra Tek, is a biology-based company concerned with reforestation and reclamation of lands damaged by natural or manmade events, such as mining, that have resulted in erosion or other deterioration of the original plant life. The company is a leader in the use of tissue culture techniques to propagate improved species, and has recently become active in the development of techniques for producing hydro-carbon compounds from plants which may be used for chemical feedstocks or fuels.

Evans and Sutherland Computer Company was originated by two Computer Science professors at the University of Utah in 1968. The company is a leading producer of computer graphics and simulation systems. It is located adjacent to the

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[3] Senate Small Business Joint Hearings Record, Aug. 9 and 10, 1978, pp. 523–524. U.S. Government Printing Office No. 34–270 O.

campus in University Research Park and interacts effectively with the University. This company employs 300 people and has sales in excess of $17 million per year.

Cerramatek, Inc. was founded in 1976 by two University of Utah Materials Science and Engineering professors to commercialize a ceramic element developed for use in a high performance sodium-sulfur battery. Motion Control, Inc. is a biomedical engineering firm founded by professors from the University's Departments of Surgery and Mechanical Engineering. The firm is developing a sophisticated products which are largely a fall out from sponsored research projects on the campus, including an advanced artificial arm controlled by the patient's natural nerve impluses and an iontopheresis device for inserting anesthetizing drugs into the body without breaking the skin.

The Utah Innovation Center has been established to further enhance the formation of new high technology business start-up. The center is funded by a National Science Foundation grant. I serve as Director on a part-time basis maintaining my regular appointment as Professor of Mechanical Engineering. The Associate Director, Dr. Ramon Johnson, is Professor of Finance and Associate Dean of the College of Business. William R. Bowen is the full-time Administrator and day-to-day manager of the center. A brochure describing the center's programs and activities is attached.

Characteristic features of the Utah Innovation Center are:

1. Joint conduct of the program under the auspices of the Colleges of Engineering and Business.
2. Modeling the program objectives after the new venture requirements of the professional venture capital industry.
3. Focus of the program exclusively on ventures with a reasonably high level of technology.
4. Orientation of the program toward utilization of university-developed technology, with target technologies identified parallel to the specific strengths of the University's research program.
5. Direction of the program strongly toward encouragement of startup ventures in preference to licensing or other alternatives.

The Center's activities are organized into the following program areas: (a) education program, (b) innovation projects, (c) new enterprise development projects, (d) research on the innovation process, and (e) public affairs.

*Education program*

The objectives of the education program are to equip students with the background, skills and experience to generate innovative ideas, develop them into useful products and to establish and operate successful businesses. A two-quarter course sequence is offered jointly through Engineering and Business entitled, "Innovation and Entrepreneurship." Student teams are assigned the task of developing business plans to manufacture and market products selected by the faculty from concepts presented to the center. Lecture sessions are devoted to engineering and business principles pertinent to the products. A number of guest lectures are given by successful technical entrepreneurs.

*Innovation projects*

Innovation projects are defined to be projects which are sufficiently promising to justify significant attention and investment of a moderate amount of funding (less than $5,000) for services but not mature enough to warrant anticipation of a new venture based on the subject.

Technical services to refine the innovation are provided through existing resources of the College of Engineering. Such services include technical consulting by members of the faculty, analytical or test services, and prototype fabrication of a wide range of devices.

Business services are conducted through the auspices of the College of Business. Consulting services are provided by the faculty of the college. Planning surveys and in-depth feasibility assessments are performed by MBA students under the supervision of selected senior faculty representing the disciplines of management, finance, marketing and accounting.

*New enterprise development projects*

New enterprise development projects are a step beyond innovation projects. They are projects sufficiently mature and promising to justify further commitment of the center's resources. The goal is to advance the project from the point of technical and business feasibility through the pre-venture capital stage to an operational business organization. New enterprise development projects are our primary means of identifying, recruiting and training managers. These managers are obvious candidates for

management roles in businesses organized under the guidance of the center. The end goal of the new enterprise development project is the formation of a new company. The center staff will provide further assistance to those projects which appear to have real potential for success, by helping to locate venture capital and recruiting additional talent for the management team. The prestige of the University is a great asset to this latter activity.

Examples of the center's direct assistance program include the following:

Robert N. Williams approached the center with a plastic model of a new automatic, continuously variable speed transmission for use on bicycles and light power drives. Prior to contacting the center, he had presented his invention to numerous firms without success. The center provided engineering assistance and paid for the fabrication of a steel model suitable for use on a bicycle. When complete, the inventor was encouraged to demonstrate his product at a national meeting as part of the Utah Innovation Center's presentation. Further publicity was given by press releases from the University and the National Science Foundation. Mr. Williams has now formed a company with private capital to commercialize the transmission. He is currently discussing contractual arrangements with several companies who desire to use the transmission for light power vehicles such as snowmobiles, motor bikes, lawnmowers, as well as bicycles. In addition the transmission is being considered for applications in home appliances and light industrial devices.

Business plans have been developed by the innovation classes for two projects which are currently receiving further support by the center. One project involves a fiber-optics temperature probe which may be used in the microwave hypothermia treatment of cancer, patient monitoring and other applications where conventional sensors using metallic conductors are inappropriate. The other is a dental drill with improved cooling characteristics. The center is aiding in the further development of both products and attempting to determine if they are commercially viable.

The center assisted in analyzing the marketing potential for a minature chemical sensor developed by engineers in our Bioengineering Department. Medical applications on the University-owned patent have been licensed to a large U.S. firm. The center is now assisting in examining the potential of the non-medical market.

A meterologist, who has developed an electronic weather forecasting device, is currently being assisted by the center. An improved model of the device is being fabricated in the University's Instrumentation Research Laboratory, and a graduate student in the College of Business has been hired to develop a business plan.

Several other projects are under consideration by the center, including an advanced design methodology for VLSI (very large scale integrated circuits), a machine for the production of concrete roof tiles, and a modular milling system for small, high-grade ore deposits.

The center's primary resource is the vast wealth of talent and facilities existing at the University. Any major university contains a formidable array of specialized talent which could be marshalled to further technical innovation. With assistance from the National Science Foundation, the Utah Innovation Center is attempting to utilize the personnel and facilities of the University to aid innovators and entrepreneurs in starting new businesses or expanding existing ones.

Our center is attempting to establish a small equity or royalty position with the companies it assists to provide operating income for the center in future years. However, the time required for a new company to reach maturity and pay dividends is long. Our center will have to rely on other sources of funds such as continued government funding, industrial contracts or gifts to provide interim financing for eight or ten years until equity positions yield sufficient income to make the center self-sustaining.

Although our center is still very young, we are impressed that the concept has merit and we recommend it to others. The financial and moral support from the National Science Foundation has been indispensible to the center. The reputation of the National Science Foundation has gone a long way to establish credibility for the center in the academic atmosphere where such an activity is somewhat unusual.

This point bears further elaboration. In general, universities are so preoccupied with their traditional and proper roles of teaching and research that they do not place great emphasis on technological innovation. Also, there is a natural tendency for universities, as large organizations, to prefer to deal with other large organizations, especially regarding applied research or commercially-oriented activities.

By the strength of its own R&D reputation, a large firm may in fact lend prestige to a university program or to an individual faculty member. The fledging technological entrepreneur cannot. Large corporations can make a long-term financial commitment to joint R&D programs such as Monsanto's 12-year, $25 million program with Harvard Medical School. In contrast, the individual inventor-entrepreneur

may have had to borrow from his child's college fund or refinance his house just to pay his patent attorney. The large firm may be an economic force in the region and a significant employer of graduates and, therefore, have easy access to the university. Therefore, while some large industrial firms have established channels through which they can gain access to university resources, it is generally true that smaller firms and start-up ventures are usually less able to interact effectively with universities.

Historically, however, individuals and start-up enterprises have been extremely productive sources of innovation. The American inventor-entrepreneur, in contrast to other advanced industrial societies, has been almost unique in his ability to create new successful technology-based business enterprises. The concern, therefore, arises that the legislation presently before Congress may, in fact, result in service to established firms while not properly addressing the needs of individual inventors and start-ups. In light of the impressive record of innovative contributions made by this sector, it seems appropriate to specify in the legislation that their unique needs be met as well as those of the established large technology firms which provide the bulk of the U.S. production capacity.

In conclusion I quote again the sound reasoning of the Charpie Report which has stood the test of time. On page 18 the report states, "It goes without saying that the United States could not depend solely on the innovative contributions of the small firms. The large firms are indispensible to economic and technological progress. From a number of points of view, however, we are persuaded that a unique cost-benefit opportunity exists in the provision of incentives aimed at encouraging independent inventors, inventor-entrepreneurs and small technologically-based businesses. The cost of special incentives to them is likely to be low. The benefits are likely to be high." [4]

It is our recommendation that Congress endorse the Innovation Center concept and provide funds to expand the program undertaken by the National Science Foundation.

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ATLANTIC RICHFIELD CO.,
*Los Angeles, Calif., August 6, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Thank you for sending us a copy of S. 1250 for review. We certainly agree that there is a need to encourage technological innovation and that it can be done in many ways. An important aspect of such encouragement is the development of closer ties between universities and industry. Our Company has recognized this through significant grants from the Atlantic Richfield Foundation to a number of technologically oriented universities.

We believe that your proposal would serve to provide an additional resource for the development of industrial technology but that it has a major flaw in regard to ownership of the new technology. In general, it is the practice of industry to require that all inventions made in the course of any consulting, research or development work be assigned to the company funding the work. Your proposal requires that title to such technology remains with the Center, if any support by Federal funds is involved. In view of this requirement, we seriously doubt that enthusiastic industrial participation would result. One possible way to mitigate this problem would be to provide for the industrial sponsor to be granted a non-exclusive license to any invention developed under his financial support and that he also be allowed to share in the royalties in relation to his proportion of sponsorship. Under such a system, an industrial sponsor would have an incentive to support work that is also supported by Federal Funds.

We are pleased to see that you and your associates are addressing the problem of reduced technological innovation in the United States. We believe that the key to increasing innovation is to establish a system that allows the innovator an opportunity to profit from his invention. I hope that additional legislation will be designed to promote this concept.

Very truly yours,

HOWARD A. SLACK.

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[4] Ibid., page 528.

NATIONAL SCIENCE FOUNDATION,
*Washington, D.C., August 10, 1979.*

Mr. MIKE CRISP,
*Minority Staff, Senate Committee on Commerce, Science, and Transportation, Dirksen Senate Office Building, Washington, D.C.*

DEAR MR. CRISP: Thank you for your letter of July 12, 1979, regarding our testimony on S. 1250 and requesting responses to a series of questions.

*Question 1. Anti-trust implications*

There are always potential anti-trust implications when two or more companies in the same industry interact. The question becomes more serious as the number of companies cooperating or their individual size or share in the market increases. However, under the conditions of our experiment with university-industry centers, the prospect of two companies that are competitors in the same industry raising serious anti-trust questions is low. First of all, each center, as part of our recommendations, would have companies representing various industries; in most cases, only one or two companies from an industry would be represented, and, usually, they would not be in competition with each other. Secondly, the National Science Foundation recommends that the university take the lead role and allow open access (on a fair and reasonable basis) to information generated at the center, that membership in center activities be open to all that can pay the appropriate fee, and that research results ultimately be published in the open literature. These actions further reduce the potential for anti-trust implications. In the final analysis, and, in order to put potential anti-trust problems to rest, it might be advantageous to receive opinions from the Justice Department on specific cases.

*Question 2. Incentives*

Incentives, in general, appear adequate in S. 1250. The most important incentives are found under Section 6 (a)(1) and (b)(1)–(4) calling for participation of individuals from industry and universities in cooperative technology innovation activities. This could be improved upon by indicating that the research agenda should be developed jointly by the university and industry partners. Also highly important are the provisions under (c)(3) calling for the center to become self-sustaining, if feasible, and the provisions under (e)(1)–(7) concerning patents.

*Question 3. Exclusive licenses*

The disposition of exclusive licenses should be decided by the center (university-industry partners), and, as such, the patent provisions in S. 1250 are similar to those successfully used in our experimental university-industry centers.

*Question 4. Commercialization*

It is recommended that the centers be initially established with strong private sector involvement (as with our experimental centers); and if the research principles are developed jointly, one can expect a smooth flow from the center to the participating companies. Thus, the participants would have the option of determining how far to go in commercialization of any product or process. Transition from university to industry would also be improved by involving industrial scientists working at centers or center scientists working at industry.

*Question 5. Tax and regulatory policies*

We have no findings on the above but feel that research and development centers should confine their direct actions to those outlined in the Bill, as hown in Section (b)(1)–(4). Any efforts concerning Federal regulations and tax policies should be confined to studies and fact finding in the technologies and industries involved in the center. This should be accomplished with participation of the appropriate Federal agencies.

A final suggestion, according to our findings, is that the activities listed under section 6(b)(1)–(4) are appropriate to two separate operational structures. Paragraphs (1) and (3) correspond to a major center that deals with existing business, mostly on the medium to large size, while paragraphs (2) and (4) are related to centers emphasizing emerging business, either new or on the small size. Our experiences indicate that these should be separately organized and directed but may be under the cognizance of an umbrella-type organization. The above recommendations are based upon findings from our experimental university-industry centers and may

require modifications for other types of centers. Please call upon us if you need additional information or comments on your proposed legislation.

Sincerely yours,

JACK T. SANDERSON,
*Assistant Director for*
*Engineering and Applied Science.*

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CHEMICAL MANUFACTURERS ASSOCIATION,
*Washington, D.C., August 14, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology and Space, Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, D.C.*

DEAR MR. CHAIRMAN: Your Subcommittee recently conducted hearings on S. 1250, a bill to promote United States technological innovation for the achievement of national economic, environmental and social goals. On behalf of the Chemical Manufacturers Association, I would like to submit our views on this legislation.

The Chemical Manufacturers Association (CMA) is a nonprofit trade association having 188 United States company members representing more than 90 percent of the production capacity of basic industrial chemicals within this country.

The chemical industry is a highly competitive industry in which technological innovation is an essential element of survival. In our opinion, there are a number of factors presently impeding innovation in this country. Effective action is necessary and must be taken to remedy this situation.

It is currently becoming more and more widely recognized that the United States is falling behind the other industrialized nations in developing new technology. If not actually falling behind in the discovery of new technology, it is certainly falling behind in bringing such new technology to the marketplace. In this respect, we believe that various government disincentives are serving to lengthen the time it takes to bring new technology into the marketplace. In our opinion, this is having the long-range effect of reducing the amount of long-term basic research which is being supported by industry. Foremost among these disincentives is excessive government regulation which greatly increases the time it takes to bring a new product into the market. This reduces the incentive to support long-term projects because of the higher risk of recovering the research costs within a reasonable time period.

CMA believes that S. 1250, the proposed National Technology Act of 1979, will improve the process of translating the results of long-term research into technology which will aid the economy of the United States, ultimately increase the amount of money flowing into basic research and, finally, serve to reduce the apparent technology lag.

To this end, the establishment of Centers for Industrial Technology clearly should serve a valuable purpose if they could make the technology available on terms which will encourage its use by industry. First and foremost in this respect should be a policy of granting exclusive licenses in order that patents be commercialized. The lack of available exclusive licenses is believed to be the major cause of the present low utilization of government patents. It is our understanding that only some 4 percent of such patents have been successfully commercialized. We do agree, however, that such exclusivity should be coupled with appropriate "march-in" rights so that there could be no abuse of exclusive license positions.

Granted the basic premise of the availability of exclusive licenses, CMA feels that other areas which deserve close attention include the timeframe under which the Centers would be operating and the ultimate resting place for the royalties involved. Hopefully, the royalties could be returned to the Office of Industry Technology and any academic institution involved in obtaining the patent. This will put the money where it can continue to serve to increase research and innovation. To do this, the Centers should be funded for a sufficient period of time that a long-range program can be put into effect and become viable without the constant threat of having government support removed so that the future of any license arrangements would be put in jeopardy.

Subject to the foregoing remarks, we support the basic premises of S. 1250. There is a clear need for legislation to promote the development and commercialization of new technology, and this measure, if amended to incorporate the changes suggested herein, should accomplish this objective.

Sincerely,

ROBERT A. ROLAND, *President.*

INTERNATIONAL BUSINESS MACHINES CORP.,
*Armonk, N.Y., August 23, 1979.*

Hon. HARRISON H. SCHMITT,
*Russell Senate Office Building,*
*Washington, D.C.*

DEAR SENATOR SCHMITT: In your letter to me of July 9, 1979, you requested my response to some additional questions relating to S. 1250. I appreciate this opportunity to address these issues, and to reiterate some points in my testimony before the Subcommittee on June 27, 1979. I will address your questions in sequence.

1. Does the prospect of two companies, that are competitors with the same industry, contributing funds and personnel for a joint research project at one of the Centers for Industrial Technology present any potential antitrust questions? If antitrust problems are anticipated, what needs to be done to avoid these problems?

I understand that whether there is an antitrust exposure if two competitors engage in a joint research project depends upon many factors, including: (1) the market in which they compete and the structure of that market; (2) the position of each competitor in that market; (3) the relative strength of other competitors in that market; and (4) the competitive advantage derived from the research. If in a particular case the competitors could be viewed as combining to monopolize or restrain trade, the fact that their joint research project was carried on at a Center for Industrial Technology would not insulate them from this exposure. The exposure could usually be minimized, however, if any invention resulting from the joint research project were made available immediately to participating organizations on a royalty-free basis, and to any other organization upon request for a reasonable license fee. The amendment to the patent provision which I propose in the answer to question 3 would provide for this.

2. Does S. 1250 contain sufficient incentives to ensure significant participation of industry in the Centers for Industrial Technology Programs? What are the most important incentives contained in S. 1250? Can you suggest any changes in S. 1250 that would increase the incentive for private sector participation?

I believe that, as a general rule, an industrial organization will prefer to manage its resources by carrying out research and development in its own laboratories. An industrial organization should have an incentive to participate in joint work, however, if it believes that the potential benefits warrant an exception. Such an exception would usually require that the work be relevant and of exceptionally high quality, that the organization have a right to use any developments, and that the organization's contributions be supplemented through the use of funding by other organizations, including the government's tax revenues, where appropriate. Of these considerations, quality is key: only if the Center does truly outstanding research and development will significant participation be obtained. The organization's right to use any developments can be achieved through satisfactory patent provisions discussed below. In terms of the government's participation, the government's use of tax revenues could be tied to industrial participation by a matching program.

3. The bill S. 1250 has a provision which would allow issuance of an exclusive patent license if industrial support or commercialization requires it. Who do you think should decide that an exclusive license is required? Are the patent provisions of S. 1250 appropriate for the Centers?

An exclusive patent license is generally inconsistent with the antitrust exposure associated with joint research projects. I have previously testified that the patent provisions of S. 1250 should provide to a participating company "freedom of action" rights to patents arising from projects in which that company invested. Attached is a proposed amendment to section 6(e) of the bill that not only provides for such "freedom of action" rights for participating companies but minimizes the antitrust exposure as well.

This amendment protects the right of a participating company to benefit from its own investment through an immediate, royalty-free right to practice inventions. As I mentioned before, without such protection, private sector participation may be discouraged.

4. The bill S. 1250 discusses the commercialization of inventions that are developed at the Centers for Industrial Innovation. At what stage in the "commercialization" process should the Center step aside and let the private sector take the product the rest of the way to the market place?

I feel that determining rules for "stepping aside" is not an appropriate matter for legislation or regulation but is instead a management issue. The management of the Center should develop these criteria on a case by case basis after consulting with its industry participants and its government contact.

The Centers should carry out research of generic importance to industry and let individual concerns do the necessary follow-on proprietary work. However, the ultimate objective of the Office of Industrial Technology is to achieve commercialization. As an example, we in IBM encourage the research groups to go to considerable lengths to convince product groups that a new development should be commercialized. To assure an appropriate balance, you might consider having a panel of industrial experts periodically review the success of the Centers in meeting their objective.

5. The bill S. 1250 creates the Office of Industrial Technology within the Department of Commerce. This office will serve as the focus for innovation policy in the United States government. Do you feel that it would be appropriate for this office to perform the function of scrutinizing Federal regulations and tax policies that are identified as serious impediments to innovation in the private sector? Can you suggest any changes in S. 1250 that would make the Office more effective in combating burdensome regulations and inappropriate tax policies that are barriers to innovation?

I have testified that the legislation should require the Secretary of Commerce to examine *all* the factors which, taken together, determine the innovative and productive vitality of our nation's industry. This would include a responsibility to examine the effect of regulation and tax policy and to propose needed changes.

Thank you for this opportunity to help you develop an effective approach for enhancing this country's innovative capability.

Sincerely,

LEWIS M. BRANSCOMB.

Attachment.

Additions to S. 1250, Section 6(e):

"When the invention is made or conceived by an individual participating in cooperative industry-university basic and applied research effort under auspices of the Center, such individual, or party to whom the individual has agreed in writing to assign the invention, shall have an irrevocable, royalty-free right to practice the invention, or have the invention practiced on its behalf, with the right to grant sublicenses of the same scope; and

"any organization participating in cooperative industry-university basic and applied research effort under auspices of the Center during the time that the invention was conceived or made shall have an irrevocable, royalty-free right to practice the invention, or have the invention practiced on its behalf, with the right to grant sublicenses of the same scope to subsidiaries and other affiliates within the corporate structure of the organization. Any other individual or organization shall, for a reasonable fee, have the right to practice the invention or have the invention practiced on its behalf."

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UNIVERSITY OF WASHINGTON,
COLLEGE OF ENGINEERING,
*Seattle, Wash., August 28, 1979.*

Senator ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, Washington, D.C.*

DEAR SENATOR STEVENSON: This note is in response to your invitation earlier this summer for comment on S. 1250—to promote technological innovation to advance economic, environmental and social goals.

The draft legislation strikes at a major problem confronting the nation, namely how to stimulate, nurture and transfer American ingenuity to meet contemporary challenges. Signals of concern, incidentally, stretch back to the early 1960s with enactment of state technical services legislation. In the 1970s there was a renewed initiative to at least understand the problem better through programs funded by the NSF and the National Bureau of Standards. There have also been legislative steps to provide tax incentives and other conditions of encouragement.

The track record of inept performance is not very encouraging and thus I would instantly support the diagnosis of short fall implicit in the legislation and the need to ratchet the issue to a higher level of policy concern.

At the same time, I am obliged to state my skepticism as to the remedies proposed in S. 1250. This current point of view, incidentally, is ironic in that I was perhaps the first person to suggest creation of centers for industrial technology in 1970. My reason for backing away from that concept derives from more recent thoughts I have had on the subject:

(1) We still do not understand the innovation process sufficiently to know what task to assign to such centers or to be able to evaluate their success or failure in performance of that task.

(2) The social environment has become far less favorable in the last decade for overt governmental intervention. The creation of new agencies and new functions so add to the complexity and institutional structure that, whatever their directed mission, the inadvertent transaction costs make such activities counterproductive.

(3) There is a widespread civic skepticism on effectiveness of government and a desire to reduce costs. Such perceptions are especially pronounced in those activities that are traditionally sited in the private sector.

(4) Virtually all technological activity today involves a mix of cultural and social as well as economic, commercial and technical factors. Public and private institutions are not only involved, but intricately interconnected. And finally, technological initiatives intended to meet some narrow purpose are now found to have widespread lateral and future impacts, some of which conflict with the broader matrix of social purpose.

All of this adds up to an urgent need to understand the technological delivery system and its innovative content far better. We should have in hand by now dozens of well documented case studies of successful innovation with sufficient detail to understand what factors have contributed in the past to social progress and what new circumstances may have arisen that blunt continued success.

If indeed complexity and overemphasis on short-run benefits dominates the technological environment, adding a new government agency would not have, in my view, much prospect of injecting change. Rather than elaborate on this theme, may I simply call to your attention its treatment in "Margins for Survival" that was recently published by Pergamon Press. The sub-title, "Overcoming Political Limits in Steering Technology" opens the door to diagnosis of the issue addressed by S. 1250.

If these comments prove useful in considering the refinement of the proposed legislation, I should be pleased to add other details on alternatives to proposals in the bill.

Again, my thanks for your invitation to comment.

Sincerely,

EDWARD WENK, Jr.,
*Professor of Engineering*
*and Public Affairs.*

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XEROX CORP.,
*Stamford, Conn., August 28, 1979.*

Hon. H. H. SCHMITT,
*Committee on Commerce, Science, and Transportation,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR SCHMITT: In response to the questions in your letter of June 26, 1979:

1. Your question of potential antitrust questions arising when two or more competing companies support a joint research project is one that I do not feel competent to respond to without benefit of antitrust counsel. I, therefore, ask to defer my response to this question to a later date.

2. While I agree in principle with the goals of S. 1250 and the mechanisms set up to achieve these goals, I don't believe the incentives for industry to particpate are great enough. There are two classes of incentive that must be addressed: one is the financial incentives that causes industry's stake to become sufficiently leveraged that it is motivated to expend time and resources to participate. The second has to do with the ability of a participating company to take to market any potentially proprietary output. To this end exclusivity is required beyond that called for in S. 1250, i.e., until the original investment is recovered.

3. My company will spend in 1979 $385 million on research, development and engineering. Most of this is geared toward identified product goals and technology support to assure that these products are reliable, maintainable and offer the finest quality and economics in our industry. You ask whether the $40–60 million called for in S. 1250 for the Centers for Industrial Technology is sufficient. I view this investment by the government as an experiment which will necessarily be limited by the funds available to a few selected industry candidates that will be carefully chosen. If success of the experiment is indicated, I am sure the Congress will be prepared to expand upon it; if not, we should at least know why before we continue the funding. I urge caution, however, in expecting results too soon. The cycle from

research to product may take from 7 to 10 years. But I would expect by year 3 or 4 we should have a good handle on whether we are on the right track.

4. As mentioned earlier, for industry to be motivated to participate in the Centers and to expend the resources necessary for follow-on activities that could promote inventions originating in the Centers to innovations, it must be assured of a degree of exclusivity far beyond that provided for in S. 1250. The bill purports to give exclusivity until the company's investment is recovered. This would not be considered by industry an appropriate incentive. Because of inherent risk factors in R&D investments and the discounted present value of earnings realized in later years through R&D investments today, industry must expect to retain an exclusive position over a period considerably longer than that required to recoup its initial outlay. It may require some form of competitive bidding among participant companies to determine the exact terms of patent allocations, but this too may have antitrust implications which I do not feel competent to address, but which will be considered in the subsequent letter on antitrust questions.

5. The Center should carry a program to the point where feasibility of product or process function is demonstrated. Scale-up, pilot plant, engineering and manufacturing prototypes should be the province of the participating company. It may turn out that to stimulate the innovation process incentives will have to be provided as well for those steps and there well may be initiatives developed by the Congress through the government procurement process or other alternative means. But that should not be confused with the principal missions of the Centers which should be to seek a means to provide relevant generic technology.

6. Indeed, I do believe that it would be useful to focus within a single office in the Department of Commerce responsibility for monitoring the state of health of U.S. industrial technology, supervising the initiation of new government incentives to stimulate innovation such as the proposed Centers for Industrial Technology and take the leadership on behalf of the government in developing policies to overcome other barriers to innovation. In a way, it is a natural follow-on to the activities of the Domestic Policy Review conducted for the President by the Department of Commerce, an exercise which I consider to have been eminently successful.

I hope, sir, that these comments will be helpful to you in furthering your already effective support for a new initiative in stimulating industrial innovation as manifested by S. 1250.

Sincerely,

J. E. GOLDMAN,
*Senior Vice President*
*and Chief Scientist.*

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INDUSTRIAL RESEARCH INSTITUTE, INC.,
*New York, N.Y., September 5, 1979.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space,*
*U.S. Senate, Washington, D.C.*

DEAR MR. CHAIRMAN: The Industrial Research Institute (I.R.I.) is encouraged by the interest you have continued to demonstrate about the state of innovation in America. I.R.I. has become increasingly concerned about the adverse impact of some undue or inefficient regulations on the innovative capabilities of the United States, and we recently prepared a position statement that addresses this problem and includes a number of recommendations.

We are pleased to submit this paper and respectfully request your consideration that it be included in the record for the hearings which your Committee has been holding for S. 1250, and similar legislation. We would also like to ask that this paper might serve as a basis for testimony by the I.R.I. during future hearings which your Committee might hold on innovation and/or regulatory reform.

THE I.R.I. is an association of nearly 260 industrial companies who are represented by their Vice Presidents and Senior Research Managers for research and development. The combined research investments of these companies account for 85 percent of this nation's total industrial research effort. I.R.I. believes it is uniquely prepared to contribute to regulatory reform activities by addressing issues having an impact on innovation. We trust you will find our contribution both constructive and helpful.

Thank you for your consideration of this request. If we can be of further help, please let me know.

Very truly yours,

JASON M. SALSBURY, *President.*

Enclosure.

POSITION STATEMENT ON THE IMPACT OF REGULATION ON INNOVATION

The Industrial Research Institute (I.R.I.) recognizes the essential role of government in achieving cost-effective societal benefits that would not otherwise occur as a normal consequence of free-market forces. Regulations are frequently utilized to achieve desired social objectives. The total cost associated with regulations must be assessed and be commensurate with anticipated benefits. One of the effects of government regulations is an impact on the rate and direction of innovation in the private sector. Because of the significance of innovation on our economic well-being, it is important that regulations be drafted in a manner to minimize their negative impact on innovation.

Representing some 85 percent of the industrially-funded research and development efforts in the United States, the I.R.I. has a fundamental responsibility to foster industrial innovation for the benefit of society as a whole. Its 258 member companies are uniquely positioned to understand the interaction between regulation and innovation. Because of this responsibility and access to understanding, I.R.I. is concerned that: (1) Regulations are unnecessarily and unintentionally stifling the industrial innovation process, whereas with proper consideration, equivalent regulatory results could be accomplished while stimulating technological innovation; (2) regulatory compliance is diverting an excessive portion of the finite technical and financial resources from new product and process innovations.

Despite recent progress in improving both the effectiveness and efficiency of the regulatory system via such actions as President Carter's Executive Order 12044, "Improving Government Regulation," the Administration's Domestic Policy Review on Industrial Innovation, the establishment of the Regulatory Analysis and Review Group and the Regulatory Council, a series of legislative initiatives under preparation and/or pending in Congress, and commendable progress in deregulation of price and entry-regulated industries, the I.R.I. believes additional steps need to be considered.

The Industrial Research Institute believes that all legislation and policies relating to the implementation of new and revised regulations should continue to require all regulatory agencies to: publish a periodic prospective agenda of regulations planned for development or review; and encourage and provide an early and meaningful opportunity for public participation in the development of regulations, including appropriate participation by technical experts from industry and academia.

SPECIFIC RECOMMENDATIONS

I.R.I. specifically recommends the following policies:

*A. Ensuring that regulatory decision making is broadly responsive to the needs of society, the capability of society to afford the requisite costs, and the efficient use of finite technical resources*

The needs of society include an upgrading of both the quality of life and the economic well being of its citizens. To make such upgrading possible, society needs to maintain an adequate rate of industrial innovation. Since the regulatory process affects the rate of innovation, it needs to be managed so that on balance its benefits outweigh negative effects on innovation.

To accomplish this, the President and Congress should require all regulatory agencies to determine that for each regulation—

(a) the proposed regulation is needed and is not redundant; when it impinges on other regulation, coordination has been provided for;

(b) the direct and indirect societal costs and effects of the regulation have been adequately considered including the effect on industrial innovation;

(c) alternative approaches have been considered and the least burdensome of the acceptable alternatives has been chosen; and

(d) a plan has been incorporated for measuring the effectiveness of the regulation some finite time after its issuance to warrant continued implementation.

*B. Ensuring that the hidden cost of uncertainty and time delay introduced by the regulatory system is recognized, quantified, and minimized*

The innovation process is particularly vulnerable to the increase in uncertainty casued by the need for a new technology to be approved by an unpredictable regulatory system. In addition, time delays introduced by a regulatory agency not only increase the cost of developing new technology and the uncertainty of eventual market acceptance, but also delay society's access to its benefits. The situation is further aggravated by the possibility of subsequent changes in regulations by an

agency. Each of these factors tend to make more difficult the research and development processes which are key to effective industrial innovation.

The uncertainty of the regulatory system bears particularly hard on smaller companies, historically an important source of industrial innovation.

To accomplish this, the President and Congress should require all regulatory agencies to determine for each regulation—

(a) whether the regulatory intent can be achieved by industry or individual company "self-regulation" or "self-certification," thus avoiding agency approval of specific technical innovations;

(b) that where specific agency approval is necessary, such approval is obtainable expeditiously and predictably;

(c) that there is interagency coordination to avoid conflicting or overlapping regulations.

*C. Ensuring that wherever possible innovative ways of meeting the regulatory intent are stimulated*

It is important that technological innovation be encouraged and not stifled as desirable regulatory goals are met. Whenever possible the regulatory processes should make provision for, and stimulate the development of, new cost-effective solutions. Frequently, regulations dictate the technology to be used; even where they do not, compliance deadlines and the threat of non-compliance penalties force use of traditional technology rather than stimulate innovative and potentially less-costly technology.

To accomplish this, the President and Congress should require all regulatory agencies to determine for each regulation—

(a) whether the regulatory intent can be achieved by the use of performance and efficacy objectives as opposed to design and methodology standards;

(b) whether the compliance deadlines are consistent with allowing an innovative approach;

(c) whether sufficient resources (technical personnel and capital) are available to permit compliance in a timely and innovative manner.

The Industrial Research Institute believes that the views contained herein should be taken into consideration in the overall intended objective of the regulatory process.

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U.S. DEPARTMENT OF JUSTICE,
ASSISTANT ATTORNEY GENERAL FOR LEGISLATIVE AFFAIRS,
*Washington, D.C., October 2, 1979.*

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

DEAR MR. CHAIRMAN: This is in response to your request for the views of the Department of Justice on S. 1250, the "National Technology Innovation Act of 1979." The bill would require establishment of an Office of Industrial Technology within the Department of Commerce and of an independent Industrial Technology Review Panel to encourage increased efforts in the technology innovation area, and it would provide seed money for certain research and development programs. Our comments address only the implications of this bill for antitrust and competition policy, and the Department does not at this time take any position on the other policy issues involved in this legislation or on the need for legislation of this general type.

From the perspective of antitrust and competition policy, the most important provisions of S. 1250 are §§ 6 and 7, which involve the establishment and operation of Centers for Industrial Technology (CITs). These CITs would be affiliated with universitites or other nonprofit institutions, and among their purposes would be the enhancement of technological innovation through cooperative technology innovation activities between industry and universities, the development of a basic and applied research base in which individual firms would have little incentive to invest, and the conduct of research relevant to governmental health, safety, and environmental regulations which would minimize the costs of duplicative research. Each CIT could acquire title to any invention developed under its auspices that was supported by federal funds provided that it satisfied the requirements of § 6(e). Those requirements include, among others, that patent licensing be on a nonexclusive basis except where commercialization or industrial support for the project is not likely to be achieved without an exclusive license, § 6(e)(3), that exclusive licenses shall require reasonable and continuous effort by the licensee to advance the invention to

the market and be limited to the time necessary to allow for recoupment of investment by the licensee, § 6(e)(4), and that any federal department or agency shall have the royalty-free right to practice, or have practiced on its behalf, the invention for governmental purposes, § 6(e)(7). If these conditions were not satisfied, the government would obtain title.

Under § 7(a), the Director of the proposed Office of Industrial Technology could make grants and enter into cooperative agreements to assist CITs, and the total amount of any such grant or cooperative agreement could not exceed 75 percent of the total cost of the program or project involved. Section 6(c) requires the Director, before establishing a CIT, to consider its potential contribution to productivity, employment, and economic competitiveness of the United States and to find both that a high likelihood exists of continuing participation and financial support from the private sector and that the CIT has a plan which, among other things, would place it, to the maximum extent feasible, on a self-sustaining basis. In addition, under § 7(c)(1), the Director can impose on a CIT any other terms, conditions, and requirements that he or she deems necessary or appropriate.

S. 1250 may permit direct competitors in an industry, through joint funding of a CIT, to coordinate their basic and applied R&D programs. Before analyzing the possible antitrust implications of this prospect, it may be helpful to discuss briefly in general terms the legality of joint ventures in research and development under the antitrust laws.

Application of the antitrust laws to joint venture R&D reflects the fact that competition and rapid technological advancement are fundamentally consistent. In a competitive environment, businessmen have strong incentives to improve the quality of their products and the efficiency of their productive processes through research and development. Research and development give businessmen the means to market a better product at a lower cost and price. The vital importance of technology to the strength of American industry in general tends to increase, not decrease, the need for competition in R&D.

The importance of competition in R&D does not mean that any cooperation in R&D between competitors is necessarily illegal under the antitrust laws, and indeed such joint ventures can increase, not decrease, competition and the rate of technological development. The legality of such an arrangement generally turns on all of the circumstances surrounding it. An assessment of the legality of a joint venture in research depends on both the characteristics of the industry and the characteristics of the joint venture. A type of joint venture legal in one industry may be illegal in another, and the legality of one type of joint venture in an industry does not necessarily mean that other types are legal as well.

One relevant factor in an antitrust inquiry with respect to a joint venture in R&D involves the identity of the participants and their relationships with one another. Joint research ventures among firms in noncompeting industries create less antitrust concern than similar ventures among direct competitors. A venture among the smaller firms in an industry would normally be less likely to have anticompetitive effects than a joint project among the larger, dominant firms. Where only a relatively small part of an industry is engaged in joint R&D, the competitive incentive to innovate exists to stimulate not only members of the joint venture but nonaffiliated firms as well. Industrywide ventures that include all or most of the firms in the industry are more likely to have anticompetitive effects. A firm that knows its competitors are not pursuing independent research that may give them a competitive edge may relax its own R&D efforts and acquiesce in a passive, unimaginative joint research program because the normal competitive incentives for rapid and aggressive technological innovation have been reduced or eliminated. Further, where research is conducted on an industrywide basis, there may be some danger that individual companies may resist or deter innovation that would adversely affect their own operations. In such circumstances the pace of innovation pursued by the collective research project may be geared to that preferred by the least progressive member of the project. In short, it cannot be assumed that the bigger a venture is, the better it is.

Another relevant factor is the scope and duration of the joint research project. A project that is narrow in scope and short in duration would be less likely to have substantial anticompetitive consequences than a broader, lengthier project. In addition, a venture that is limited to basic research usually raises fewer antitrust concerns than joint efforts in applied research, which, in turn, generally raises fewer concerns than do joint development efforts.

An important consideration in antitrust analysis of joint R&D projects is the ability of the participants to conduct similar research individually. If participants can show that the cost and risk of the research are so great that they would not

have undertaken the project individually, then the venture may have the effect of increasing rather than decreasing competition. This may happen, for example, if individual firms in a relatively unconcentrated industry lack the resources to finance independent R&D projects on the most efficient scale. In some industries, however, barriers to entry in R&D are not high enough to exclude small firms from efficent and effective participation on an individual basis or on a joint basis in a project of modest scale. Projects with huge budgets and staffs are not necessarily the most productive or the most imaginative. Further, a small firm with a promising idea that would enable it to gain a significant competitive edge over its rivals may well be able to raise the capital necessary to pursue the project.

The antitrust laws also take into account the extent to which independent programs in R&D would create unnecessary and wasteful duplication of effort. In some circumstances, industrywide cooperation may be more efficient in producing more innovation for each R&D dollar. In other circumstances, competing research efforts in the same area may not be needlessly duplicative, and they may focus on different ways to solve the same problems and result in more and faster progress.

Another aspect of joint research ventures which must be carefully scrutinized is access by nonparticipants to the benefits of the venture. It is well established that exclusion of actual and potential competitors from the opportunity to share the results of, as well as to participate in, a joint research project on a reasonable basis may be a ground for concluding that the joint project violates the antitrust laws.[1] Where access to a facility created by a combination among competitors becomes essential to effective competition in a particular market such that exclusion from membership in that facility places an enterprise at a competitive disadvantage, it may well be unlawful under the Sherman Act to continue the operation of the facility without providing access to all competitors who desire admission.[2] This may be true even though competing facilities exist,[3] or where competition is not completely prevented by the presence of the facility but is only made more difficult.[4]

Finally, attention must be paid to any collateral restraints and activities of the joint R&D program. A joint venture that is otherwise legal may nevertheless violate the antitrust laws if it imposes unreasonable collateral restrictions on the participants. For example, an agreement by the participants not to engage in independent research, or not to use technology developed by nonparticipants unless the technology is available to all participants, tends to restrain competition in research and development. Other types of activities by joint venturers, such as the sharing of confidential information about costs, prices, and similar matters could tend to reduce or eliminate competition among them, and the venture should be structured in a way to avoid this kind of information exchange among competitors.

This discussion of the comprehensive, broad-ranging inquiry of joint R&D projects which the antitrust laws require demonstrates the reasonableness and common sense of antitrust analysis. The antitrust laws are not hostile to joint ventures in R&D, and they reject any presumption that joint research ventures are necessarily anticompetitive and anti-innovative. But the antitrust laws also recognize that joint research is not alway more effective than individual research and that bigger joint research projects are not always better than smaller ones. Joint research activities may be necessary for some firms in some industries, but independent R&D remains the most effective menas to technological development and innovation for many firms in many industries.

With these thoughts in mind, it is clear that the antitrust laws are consistent with and complementary to the objective of S. 1250 to expedite the rate of technological innovation in the United States. S. 1250 apparently contemplates continued applicability of the antitrust laws, and we suggest that continued antitrust applicability should be made clear in any legislation along these lines, because it would reinforce the provisions of the bill and insure that particular CITs would be organized and operated in a manner that would not interfere with the efforts and incentives of individual firms to pursue technological research.

S. 1250 recognizes the importance of individual, competitive research. For example, one of the objectives of the CITs under § 6(a)(2) is to develop a research base "in which individual firms have little incentive to invest", and implementation of that goal would minimize the extent to which cooperative R&D would displace R&D conducted by individual firms. Safeguarding this kind of focus is appropriate and necessary. If joint activity and government subsidy are not necessary for an effec-

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[1] *Associated Press* v. *United States*, 326 U.S. 1, 15 (1945).

[2] *United States* v. *Terminal R.R. Ass'n of St. Louis*, 224 U.S. 383 (1912).

[3] Associated Press, supra at 17–19.

[4] *American Federation of Tobacco Growers* v. *Neal*, 183 F.2d 869, 872–73 (4th Cir., 1950); *Gamco, Inc.* v. *Providence Fruit & Produce Bldg.*, 194 F.2d 484, 487 (lst Cir.), cert. denied 344 U.S. 817 (1952).

tive attack on the technological problems facing an industry, approval of a CIT in that industry would be inappropriate from the perspective of both S. 1250 and the antitrust laws, and in industries where joint activity and government subsidy are needed, a CIT with a larger size, scope, or duration than is shown to be necessary would similarly undermine the policies of both S. 1250 and the antitrust laws.

It would be premature for the Department to express views on the patent rights provisions of S. 1250 until it completes its current review of the issues concerning ownership of patent rights to inventions financed wholly or partly by federal funds. We note only that unlike other legislation permitting contractors to obtain exclusive rights to federally funded inventions, the bill does not provide for government march-in rights. Such rights are normally granted to assure that the government will be able to act if the private ownership of the invention becomes inconsistent with antitrust, public health and safety, or regulatory policies.

We hope that these comments will help in an analysis of the specific provisions of S. 1250 if it is decided that legislation of this general type should be enacted. Whether legislation along these lines should be enacted involves policy considerations as to which the Department of Justice makes no recommendation.

The Office of Management and Budget has advised that there is no objection to the submission of this report from the standpoint of the Administration's program.

Sincerely,

ALAN A. PARKER,
*Assistant Attorney General.*

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NATIONAL ASSOCIATION OF MANUFACTURERS,
*Washington, D.C., October 4, 1979.*

Hon. ADLAI E. STEVENSON,
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: We noted with great interest your introduction of S. 1250, The National Technology Innovation Act of 1979. The Task Force on Innovation Legislation of the NAM Committee on Science and Technology sees S. 1250 as a constructive legislative effort to address some of our current problems in industrial innovation.

We are submitting a statement on S. 1250 developed by the Task Force on Innovation Legislation for the record of your hearings on the bill. While recognizing, in general, the thrust of the legislation in attempting to solve some of this nation's technological problems, we have strong reservations as to the effectiveness of many of its provisions.

Yours sincerely,

BRENDAN F. SOMMERVILLE.

Attachment.

STATEMENT OF THE NATIONAL ASSOCIATION OF MANUFACTURERS

The National Association of Manufacturers represents more than 12,000 member companies which employ a majority of the country's industrial labor force and which produce more than 75 percent of the nation's goods. More than 80 percent of the NAM's members are generally classified as small businesses. The Association also is affiliated with an additional 158,000 businesses through the National Industrial Council.

The NAM, as represented by the Task Force on Innovation Legislation of the NAM Science and Technology Committee, appreciates this opportunity to comment on S. 1250, the National Technology Innovation Act of 1979.

It would be superfluous to repeat here all of the problems that this nation now recognizes are at the heart of industrial innovation. There is no reason to restate what has become so obvious to all of us in industry and what is becoming obvious to members of the Congress.

We applaud a number of new efforts both in the Senate and the House of Representatives to address the pieces that make up our whole problem in this area—the pieces being patents and licensing, research and development spending, the problem of basic research, the transfer of government-owned technology to the private sector, the reform of our tax laws, programs for capital recovery allowances, and so on. These pieces all have an impact on industrial innovation. Constructive changes in these areas can contribute to the revival of the scientific and technological genius that is part of our national reputation.

We applaud in general S. 1250, The National Technology Innovation Act of 1979 as representing one Congressional response to the need to get moving in solving some of our technological problems.

First, let us generalize a little about industrial innovation. As we read the newspapers and the popular weekly magazines, as we listen to discussions on this problem, we get a distinct impression that a lot of people mistakenly equate innovation with research and development. The simplistic argument goes: If we just pour more and more billions of dollars into research and development, be it in the federal government, the universities, or the industrial laboratories, we will be able to rejuvenate our lagging innovative strengths. Industrial innovation in the United States will resurge, and we'll be out there in the market—our domestic market as well as the international markets—with renewed technological strength. We'll beat back the competition, our productivity will be given renewed growth, employment will rise, social problems in health, safety, and the environment will be whipped, and we'll all live happily ever after.

The argument is not only simplistic, it's downright dangerous. Innovation has very little to do with pouring more and more billions of dollars into research and development. Innovation is the process of taking the results of research and developoment—the discoveries, the inventions, the improvements—out into the marketplace. We have a plethora of research results—as the astronomical growth in scientific literature will attest. We have plenty of results from government research—as the 28,000 or more government-owned patents that we all worry about also attest. In general, research and development in this country are in good shape, even if our R&D dollar is being chewed away by inflation and misguided tax policies. We spend more on research and development than any other country in the world, and still more than a number of major countries put together.

Our problem is taking those results, bringing them to the marketplace, and making a profit from doing it. And making the profit from doing it is really the key factor in stimulating industrial innovation.

Although industry itself is not altogether blameless when fingers are pointed as to where our problems lie, it is our conviction that government, its policies, its agendas, its regulators, and its bureaucrats must bear most of the blame for our current setback. And that leads us to a consideration of some of the specific provisions of S. 1250. In section 2(6), the bill corroborates our view of where much of the blame lies when it says "Government antitrust, economic, trade, patent, procurement, regulatory, research and development, and tax policies have significant impact upon industrial innovation and development of technology . . ." But again, let us not overstate the obvious.

In light of the significant impact that Section 2 mentions, we are concerned first that the establishment of an Office of Industrial Technology in the Department of Commerce will expand the bureaucracy without a concomitant expectation of improvement in the government's role in the processes that are part of innovation.

As we reflect on the formation of an Office of Industrial Technology, we wonder what the existing apparatus in the Commerce Department, namely the office of the Assistant Secretary for Science and Technology, has been doing all these years.

As we understand it, among the functions of the Assistant Secretary of Commerce for Science and Technology, are:

Advise the Secretary and other Commerce officials on important questions and problems in science and technology.

Review, evaluate, and coordinate research and develpment programs of operating units involving science and technology.

Develop and assist in the initiation and implementation of new research and development programs in science and technology in furtherance of the Department's objectives.

Coordinate efforts within the Department to stimulate research and development activities in the private sector, including industry, universities and non-profit organizations, that involve science and technology and are relevant to the objectives of Commerce programs. Where appropriate, sponsor such activities.

We see strong similarities between these functions of the position of Assistant Secretary for Science and Techology and the duties of the Director of the Office of Industrial Techology as proposed in Section 5(c) of S. 1250. Thus we are prompted to ask are there not already in the Commerce Department existing mechanisms by which the objectives of S. 1250 might be accomplished?

If a Director and an Office of Industrial Technology were to be set up, what would be the relationship of the Director and his office to the Assistant Secretary for Science and Technology?

In fact, are not the duties (as in Section 5(c) of the bill) merely a set of qualifying definitions of what the Assistant Secretary's functions are already, namely, to coordinate efforts within the (Commerce) Department to stimulate research and development activities in the private sector, including industry, universities and non-profit organizations, and where appropriate sponsor such activities?

While we would be in favor of most of the duties of the Director of the Office of Industrial Techology, we would oppose the creation of such an office in the Department of Commerce. We feel that a redefinition of the functions of the Assistant Secretary of Commerce for Science and Technology so as to incorporate the specific duties listed in Section 5(c) of S. 1250 would be more appropriate instead of setting up another level of bureaucracy that is supererogatory to the existing functions in Commerce and that might well be at odds when the Assistant Secretary and the Director of Industrial Technology are doing the same things. We concur that the provision to locate an Office of Industrial Technology in the Department of Commerce is a logical one given that there is an assumption that Commerce is most able, among all other government agencies, to "Determine the relationships of technological developments and international technology transfers to the output, employment, productivity, and world trade performance of the United States and foreign industrial sectors."

We have no quarrel with such an assumption, although we have misgivings, in light of the rather poor performance of the Department of Commerce in recent years in working constructively with the private sector, that such a capability would be exercised any more productively in the future than it has in the past.

We have similar misgivings about other duties of the Director of the Office of Industrial Technology.

We are a little puzzled by the language of Section 5(c)(4), that the Director shall "assess whether the capital, technical and other resources being allocated to domestic industrial sectors which are likely to generate new technologies are adequate to meet private and social demands for goods and services and to promote productivity and economic growth." We are not clear on the meaning of the phrase "capital, technical and other resources *being allocated to domestic industrial sectors* (emphasis added)." Nor are we quite clear as to what is meant by "to meet private and social demands."

In Section 5(c)(6), the phrase "exploiting innovations of foreign origin" raises many questions. Since a recommendation for such exploitation would be from the Secretary of Commerce to the President and Congress for *government measures* to exploit foreign innovations, we question what mechanisms would be employed by the President and Congress to so exploit innovations of foreign origin. Would the U.S. government purchase licenses to such innovations? If it did, what mechanisms would be used to bring the innovations into the sphere of manufacturing industry? Innovations of foreign origin are, presumbly, already available for licensing by U.S. manufacturers should they choose to produce and market such innovations in the United States.

In Section 5(d), there is a provision that the Secretary of Commerce shall prepare and submit to the President and Congress, *within 3 years after the date* of enactment of this Act, a report on the progress, findings, and conclusions of activities conducted under Sections 5 and 6 of the Act (emphasis added). In light of recent experience in setting up government programs (for example, after signing of the Metric Act in December 1975, it was not until 1979 that the U.S. Metric Board, required under that Act, was fully staffed and operational) as complex as that provided for in an Office of Industrial Technology and Centers for Industrial Technology throughout the country, it seems optimistic that 3 years would be adequate time in which to establish a program as described in the National Technology Innovation Act of 1979 (S. 1250). Perhaps five years might be more realistic, with another five to ten years in which to bring forth any major results.

In examining the objectives of the Centers for Industrial Technology, we are concerned that the emphasis appears to be strongly tilted to more research rather than the process of innovation, which as we stated earlier, goes well beyond the research and development function.

Although there can be some value in "cooperative technology innovation activities" (and though we have some sense of what is intended by that phrase, we would like to see it more clearly defined), there remains the problem that innovations are seldon if ever brought into the marketplace through cooperative activities. In fact, such cooperation raises the issue of possible antitrust threats.

Further developing a generic research base important for technological advance and innovative activity in which individual firms have little incentive to invest, seems somewhat contradictory. Ultimately, someone must invest in the work that

can lead to innovations, and the keenest incentive is not primarily the development of a generic research base, but rather the promise that an innovation will be successfully marketed and will yield a profit.

In Section 6(a)(3), which describes as an objective of the Centers for Industrial Technology "the conduct of research that contributes to the scientific basis of health, safety, and environmental regulations for the purposes of improving regulatory actions and minimizing costs of duplicative research," surely this objective represents a substantial duplication of the mandates and responsibilities of agencies such as the Environmental Protection Agency, the Occupational Safety and Health Administration, the Consumer Product Safety Commission, the Federal Drug Administration, and others. What would the Centers for Industrial Technology contribute beyond the work of such agencies to the scientific basis of health, safety and environmental regulations?

We are not sure that Section 6(a)(4), the education and training of individuals in technology innovation could be accomplished per se. We are of the view that "technology innovation" cannot easily be taught, but even when it can, we believe that it would be more suitable to allow the existing educational institutions to do it.

We are not quite clear as to how the Centers for Industrial Technology would improve mechanisms in the dissemination of scientific, engineering, and technical information from universities to industry. The dissemination of such information seems already to be well taken care of—if not too well taken care of—by the hundreds of scientific and trade journals in all of the scientific engineering and technical fields, in patent journals, in the hundreds of scientific and technical conferences, symposia, and meetings that take place in the U.S. and abroad, and in the services available (for the work of government) from the National Technical Information Service, the technology transfer publications of government agencies (such as NASA and EPA), and so on. No doubt, their mechanisms could be improved. But the idea that a Center for Industrial Technology could contribute to the improvement of such mechanisms seems at best unlikely, and at worst, simply a duplication of the efforts that those who disseminate scientific and technical information are constantly making to improve their product.

We are wholly in favor of Section 6(a)(6), the utilization of the capability and expertise, where appropriate, that exists in Federal laboratories. Such a utilization would receive our wholehearted support since it is clear that the Federal laboratory complex represents an extraordinary capability to make substantial contributions to furthering this nation's innovation capabilities.

As regards Section 6(a)(7) we feel that there are several possible conflicts between universities and industry that could prelude success of the Centers for Industrial Technology on the scale envisioned in S. 1250.

Universities are well suited to performing basic research, generating scientific information, and evaluation of results through peer review. Industry, on the other hand, must be concerned with protecting "proprietary information," the results of applied research, and most importantly bringing those results to the marketplace. The ultimate judge of how well the private firm does this job is not peer review, but the marketplace.

For these and other reasons, it is difficult to expect a "high likelihood" of continued private sector support and participation in the Centers. The "success" of the Centers would have to be judged over a fairly long period, possibly 7 to 10 years. How would the success of the Centers be evaluated?

At this point we might relate the experience of what appears to be a very successful experiment in three universities which are carrying on a five-year program that provides a training ground and real life experiences for inventors and entrepreneurs. This has been called the Innovation Center Program. The program is being conducted at Innovation Centers at the University of Oregon, the Carnegie-Mellon University, and the Massachusetts Institute of Technology. The program, now in its fourth year, is one of six experimental projects funded by the National Science Foundation through its Office of Experimental R&D Incentives. Without going into too much detail, since the program is well described in an article in the July 1979 issue of Research Management (published by the Industrial Research Institute), the Innovation Center experiments as conducted in the three centers mentioned vary a good deal. The MIT center focuses on the early stage—the research and development and level—of the innovation—the formation of new ventures to manufacture and market new products. Finally, the University of Oregon Center specializes in evaluating an innovation and technology transfer—particularly the transfer of the technology from the noncorporate (the university or independent R&D sectors) to the corporate sector.

As described in the Research Management article, the Innovation Center Program appears to be a success. ". . . It appears that Federal incentives, beyond those of the patent system, can stimulate technological innovation by providing a more favorable environment for inventors and by providing a training ground for entrepreneurs and innovators," the article says:

"* * *the preliminary data yielded to date certainly indicate that the experiment is worth continuing and expanding to a limited number of additional centers. The infra-structure—the universities—is already in place. Because direct Federal involvement is minimal, little or no additional bureaucracy would be required to implement an expanded program."

We cite this experiment because we believe that it could yield very fruitful results. By expanding such a program, we believe that many of the excellent proposals in S. 1250 might be accomplished without setting up what might be a complex and cumbersome expansion of agency (in this case the Commerce Department) involvement.

We would ask you to give some consideration to the Innovation Center Program as a possible model—not fully formed or proven as it yet may be—for many of the Centers for Industrial Technology described in S. 1250.

We have a number of questions concerning Section 6(c) Requirements. As this section provides, the Director, prior to establishing a Center shall find that "a high likelihood exists of continuing participation, advice, financial support, and other contributions from the private sector involvement." We would prefer to use the word "commitment" as indicating a stronger intent of the kind of participation that might be sought.

In Section 6(c)(3), we believe that there ought to be some time frame for a university's or nonprofit institution's plan for management and evaluation of activities proposed with the particular Center.

In fact, that same consideration for a time frame is important in Section 6(d) Planning Grants.

Perhaps the most troubling sections of S. 1250 for the private industrial sector as represented by the NAM are Sections 6(e) and 7(c)(3).

First, Section 6(e). In exercising an option to acquire invention conceived or made under the auspices of a Center, there is a provision (Sec. 6(e)(2)) that the "Center intends to promote the commercialization of the invention and file a United States patent application." We would be interested to know what mechanisms the Center will or can use to promote the commercialization of inventions. It seems to us that the successes in existing government programs of technology transfer to the private sector have been few and far between. We do not foresee that the Centers for Industrial Technology would be necessarily any more successful in promoting commercialization of inventions from government-sponsored work.

Perhaps a major stumbling block to private sector participation in the work of the Centers for Industrial Technology occurs in Sec. 6(e)(3), concerning licensing of inventions conceived or made under the auspices of the Center. We have learned by now that federal government policies of nonexclusive licensing of inventions made under government contracts have been a failure. Any chance for involvement in the commercialization of such inventions by the private sector depends on exclusivity of licensing. There are few inventions and fewer entrepreneurs (by they small or large) that will ever be commercially successful without an exclusive license. The exception mentioned in this provision "where commercialization or industrial support for the project is not likely to be achieved without an exclusive license" should be the general provision rather than the exception.

In Sec. 6(e)(6), there is too much uncertainty about confidentiality in how the Director would deal with information. We believe that the Director should be required to treat (rather than may treat) information contained in periodic reports to the Director "as privileged and confidential technical, commercial, and financial information and not subject to disclosures under the Freedom of Information Act." Without a guarantee of strict confidentiality, private sector involvement with Centers for Industrial Technology is unlikely to be readily forthcoming.

Finally, we would express deep concern about Sec. 7(c)(3), particularly as it would empower the Secretary of Commerce, the Director of the Office of Industrial Technology, and the Comptroller General of the United States, or any of their duly authorized representatives, to "have access, for the purpose of audit and evaluation, to *any* books, documents, papers, and records of receipts which, *in the opinion of the Secretary, Director, or the Comptroller General,* may be related or pertinent to such grants and cooperative agreements." (Emphasis added).

Unfortunately, this provision for discretionary powers would be very strongly opposed by the private sector and would seriously undermine the intent of the

entire bill. They would be seen by prospective industry participants in the work of the Centers for Industrial Technology as providing an open door for fishing expeditions by government agencies, an issue that has for so long been a bone of contention in government-private sector relationships.

In summary, the NAM recognizes S. 1250 as a positive and constructive measure to try to bring about some solutions to a recognized national problem. We feel, however, that the bill, in its present form, may require substantial rewriting to make it generate the kind of cooperative interaction among the government, the universities, and the private sector that we all seek.

# An Analysis of the NATIONAL SCIENCE FOUNDATION'S INNOVATION CENTERS EXPERIMENT

an effort to promote
technological innovation
and entrepreneurship
in academic settings

## PREFACE

The Innovation Centers Experiment is part of a continuing effort by the Federal Government to test and evaluate unique institutional arrangements for stimulating technological innovation in the private sector. The suitability of replicating these institutions as a public policy is judged by a number of criteria including: importance of the problem being addressed and the leverage and effectiveness of the solution posed; the costs, legal aspects, equity, understanding, acceptance, and administration of the policy for replicating the institution and the hypothesis, design, and feasibility of the experiment used to develop and evaluate the institution.

As the experiment is reaching its end, it has shown a great measure of success from both a performance standpoint and in satisfying the posed criteria.

The data included in this report substantiates this conclusion. It is anticipated that data collected in the future will continue to show Innovation Centers as a suitable institutional arrangement on which to base a national policy.

R. M. Colton
July 1977

## SUMMARY

Innovation Centers, sponsored by the National Science Foundation at three universities, have outstanding interim results to report. These Centers have:

- participated in the creation of over 30 new ventures, of which 23 have achieved sales in excess of $30 million, have resulted in approximately 1,000 new jobs, and have generated in excess of $6 million in tax revenues;
- exposed over 2,000 students to instruction and/or experience in the entrepreneurial, invention, and innovation processes; and
- assisted in the evaluation of over 2,000 ideas for new products.

These Innovation Centers comprise an experiment, the objective of which is to determine whether the entrepreneurial tendencies of students can be enhanced by participation in academic coursework and clinical experience provided in the university environment. While early results indicate success, definitive conclusions relative to the objective will be determined only after tracking the careers of the participating students.

The interim results listed above arose directly from Innovation Center operations in pursuit of the broad objective. Functions involved in these operations included:

- idea/invention evaluation,
- assistance for new business startups,
- development of new products for existing businesses,
- formulation of innovation/entrepreneurship education curricula,
- research on the innovation/entrepreneurship processes,
- participation in entrepreneurial decisionmaking.

The demonstration and propagation of such activities is essential to the continued economic vitality of the American economic system. The past successes of this system have been based on innovation and entrepreneurship—in production, agriculture, technology, and science—but this success has resulted in a social/economic/governmental structure tending to suppress those very attributes that created it. The Innovation Centers seek to counter this trend.

Despite the absence of long-term results, it is difficult to avoid the conclusion that the Innovation Centers have demonstrated outstanding success through the interim results cited above. The measures of this success may be depreciated: (1) some of the new ventures may have come into being without Innovation Center involvement, (2) production and jobs may not be net gains due to the displacement of existing products, (3) the Innovation Centers may have a marginal impact on many of the students, and (4) idea evaluation is a difficult to

assess benefit. But ventures have been created, students have become entrepreneurs, and ideas have been commercialized successfully as a direct result of the Centers' efforts.

Each of the existing Innovation Centers at MIT, Carnegie-Mellon University, and the University of Oregon are organized differently, have a unique emphasis, and produce different products. Each is successful in its own way and appears to have a good chance for continuation past the period of NSF support. The experiment runs 5 years and terminates in 1978. After that, the Centers must become self-supporting or attract other support. In any case, it appears that the type of functions being performed by the Innovation Centers will continue in the academic environment. Other universities are emulating the Centers and are becoming increasingly aware that they can and should engage in such activities.

## INTRODUCTION

At MIT, students are developing TV games, electronic guitars, and ignition systems; at Carnegie-Mellon University, students are participating in business ventures in medical instrumentation, computers, newspapers, and prosthetics; and at the University of Oregon, hundreds of inventors are being aided in the evaluation and promotion of their ideas. These activities are not in the traditional mold of the university but are part of a National Science Foundation experiment aimed at promotion of innovation and entrepreneurship. This experiment responds to a need in the United States to actively foster the basic ingredients that allow a free technological society to retain its vitality in an increasingly structured environment.

The Innovation Centers experiment has been underway for 4 years and is producing an increasing flow of innovations, inventions, and entrepreneurial activity. The experiment shows much promise for demonstrating the efficacy of its methods and although it may not be a panacea for the general problem (there is none), this effort holds promise for helping to reverse the trend away from entrepreneurship. This report examines the experiment and its results.

The National Science Foundation began the Innovation Centers Experiment in 1973 in order to assess the ability of universities to nourish a very practically oriented effort to increase American entrepreneurship and innovation. This experiment is still underway and the final results are yet to be determined. Now, however, there are useful lessons to be derived from the experience in establishing and operating the Innovation Centers, from the mechanisms employed in carrying out the experiment, and from the interim results being obtained. Here, the experiment is described and an attempt is made to present its essence.

The objective of the Innovation Centers as stated by the NSF Program Manager is "to determine if the combination of formal classroom training in engineering and business theory and hands-on clinical experience in generating new ideas, developing and evaluating new products, and initiating new ventures can increase . . . the probability of the . . . participants becoming successful entrepreneurs."* The experiment thus couples innovation (the act of introducing something new or novel), the entrepreneur (one who assumes the risk and management of business), and a clinic (where special problems are studied by concrete examples with expert advice), with the university (an institution organized for teaching and study in the higher branches of learning). The fruit of this union is envisioned as an innovation in itself, a new process for instilling vigor in

*R.M. Colton, "Technological Innovation through Entrepreneurship" (to be published).

*The New York Times*, Thursday, November 26, 1976

**LOSS OF INNOVATION IN TECHNOLOGY IS DEBATED**
**by Walter Sullivan**

American innovation and ingenuity have lost their momentum, the chairman of the President's Committee on Science and Technology told the National Academy of Engineering in Washington last week.

Use of science and technology for the Nation's benefit is, he said, "less bold, less innovative, more timid."

The speaker was Dr. Simon Ramo, cofounder of the Ramo-Woodbridge Corporation . . . .

a sluggish economy lethargized by its unwieldy structure—an injection of creativity directed to practical needs. It is not obvious that the coupling of such disparate elements should be fruitful; thus, the experiment.

As the experiment and its results are described, evidence will be cited that indicates that the Innovation Centers Experiment is a success, that a pattern has been established for widespread adoption, and that there are a number of potential beneficiaries including:

- students and others with aspirations for becoming entrepreneurs;
- educators who wish to provide entrepreneurship opportunities for students;
- entrepreneurs who require assistance;
- policymakers and legislators concerned with innovation, productivity, entrepreneurship, economic stimulation, and innovation;
- inventors requiring evaluation of their ideas;
- venture capitalists interested in growth opportunities; and
- industries requiring new products.

This is documented in the descriptions of the problem-plan-progress-product-and-prognosis that follow.

## PROBLEM

In the United States, there is a tradition of innovation, invention, and entrepreneurship to which is ascribed a large measure of the Nation's success in achieving its political and economic success and thus a desirable "quality of life" for its citizens (see figure 1). Over the last decade, concerns have been expressed that these basic ingredients are disappearing from the American scene and that the consequences will be an erosion of this country's leadership in the world. These concerns are substantiated by data on inventions, new ventures, trade balances, technological development, and productivity. Although the causes and cures relating to the decline of the technological entrepreneur will be sought in many forms for many years, the search for responses cannot be, and is not being, deferred.

Barriers to innovation and entrepreneurship have been documented. Williams et al.* identify key barriers that include the limitations of available technology, the inability to match needs and capabilities, the unyielding structure of markets and supply systems, the size of the financial risks and rewards, the rigidity of institutional and intellectual patterns, and the inability of available organizations to mount sustained efforts to meet needs.

The status of the technology barrier depends on the vigor of research in various fields (see figure 2). The other barriers are direct derivatives of our socioeconomic structure and yield only under the pressure of that structure. But they are only barriers and are susceptible to circumvention.

However one may view these barriers, it is a fact that innovation in the United States has decreased to a dangerous extent. The U.S. Patent and Trademark Office reports patent award data indicating that U.S. patents awarded to foreign inventors exceed those awarded to U.S. inventors by a wide margin in several special areas† and, across the board, the ratio of foreign to domestic patents is rapidly increasing (see figure 3). Gee and Tyler‡ have reviewed barriers to innovation with particular emphasis on the regulatory and bureaucratic impediments and also draw convincing links between the reduction in innovation and a declining rate of growth in U.S. productivity (see figure 4), the shrinking

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*C. Williams, E. Milbergs, R. Quick, and J. Ford, ***Planning and Evaluation Assistance to the NSF Experimental R&D Incentives Program,*** Stanford Research Institute, Menlo Park, California 94025, June 1973 (Contract URU-72-66, RDI Report No. 17).

†***Technology Assessment and Forecast, Sixth Report***. U.S. Patent and Trademark Office, Washington, D.C. 20231, June 1976 (PB-254-188).

‡E.A. Gee and C. Tyler, ***Managing Innovation***, John Wiley, New York, 1976.

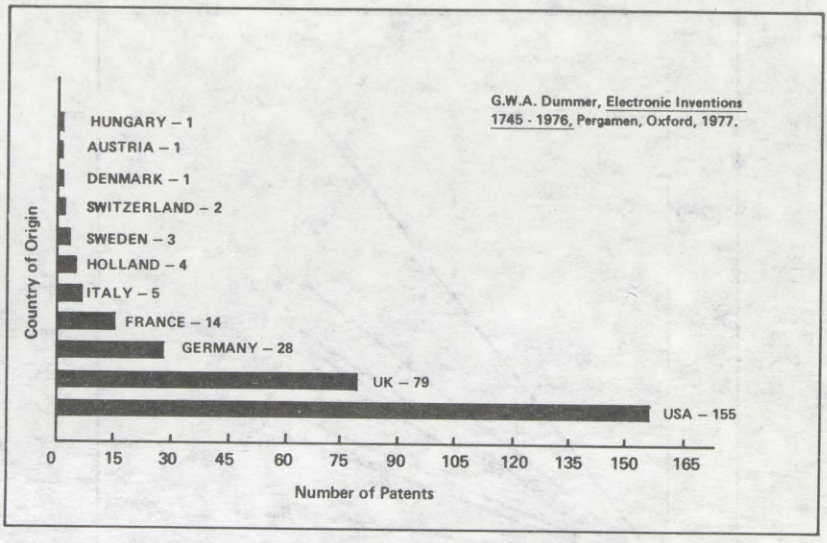



Figure 1. Countries of origin of electronic inventions (Europe and U.S.A.).

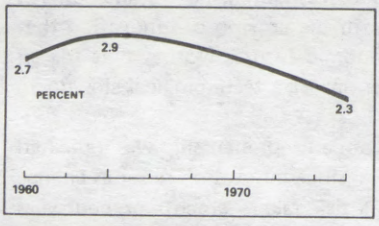



Figure 2. R&D as percent of gross national product.

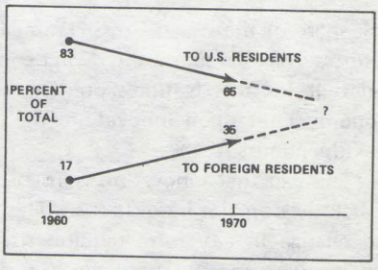



Figure 3. U.S. patents.

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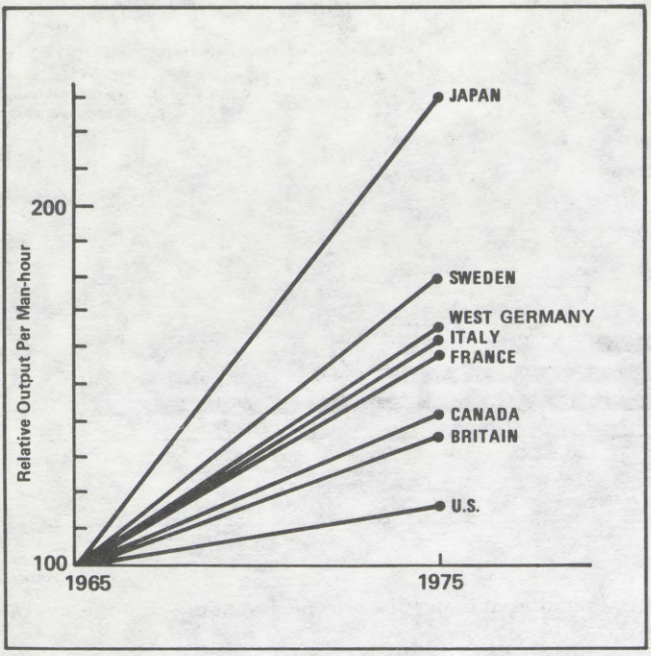



Figure 4. Productivity output per man-hour (indexed to 100 for 1965).

U.S. share of the world Gross National Product (see figure 5), and trade deficits. *Business Week** reports a growing concern with the erosion of innovation that bodes ill for this Nation's political and economic future. Noting that for an economy built upon innovation, the implications of a technological slowdown are stupendous.

The fact that innovation is inseparable from entrepreneurship was indicated in a study of major innovations.† This is logical since innovation requires change and change in any form requires risks. Thus risk takers or entrepreneurs are required who perceive both the risks and rewards in innovation, and are willing to gamble on their judgment in risk-taking. The trend has been toward a decreasing number of U.S. entrepreneurs. The need is for *more*—and this is the need to which the Innovation Centers Experiment is directed.

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*"The Breakdown in U.S. Innovation," *Business Week*, p. 56, February 16, 1976.

†S. Globe, C. M. Schwartz, and G. W. Levy, "Final Report, Interaction of Science and Technology in the Innovative Process: Some Case Studies," Battelle Columbus Laboratories, Columbus, Ohio, 1973 (NSF-C-667).

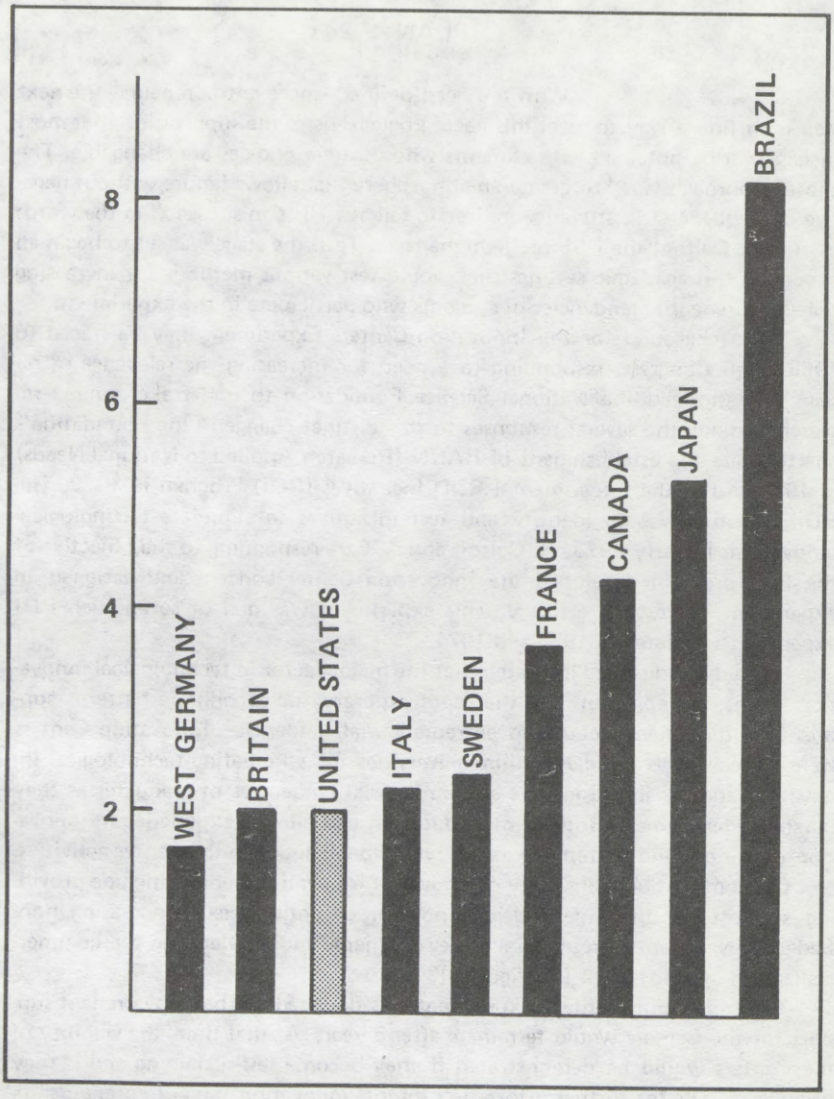



Figure 5. Average annual growth in G.N.P. (1970–1975).

## PLAN

With the need defined—more entrepreneurs—the next step is to find a way to meet this need. Logic leads to the supposition that most success will be obtained with students whose career choices are changable. The chosen approach was "to create an atmosphere that allows failure without negative consequences ..., students are free to fail as well as to succeed" in the words of Robert Colton, the NSF program manager. Thus the stage was set to begin an experiment in academic settings that would test various methods for increasing the entrepreneurial tendencies of students who participate in the experiment.

The background for the Innovation Centers Experiment may be traced to 1968 when Congress, responding to a need for increasing the relevance of research, authorized the National Science Foundation to undertake applied research. Among the several responses to this distinct change in the Foundation's charter were the establishment of RANN (Research Applied to National Needs) in 1971 and of the Experimental R&D Incentives (RDI) Program in 1972. The RDI objective was to identify and test incentives to stimulate technological innovation. In early 1973, R. Colton and A. Ezra responding to the objective of the RDI program developed the Innovation Center concept and designed an experiment to test its efficacy. This experiment was one of seven such RDI experiments initiated in 1973 and 1974.

In brief, studies had indicated that the major factor in technological innovation is the entrepreneur and that contemporary socioeconomic patterns suppressed rather than encouraged entrepreneurial tendencies. Innovation Centers were conceived as vehicles within universities for stimulating technological innovation and for increasing the entrepreneurial tendencies of graduates as they pursued their careers. Both formal education and clinical experience in innovation invention, and entrepreneurship, would be included in the Center activities.

Concomitant but subsidiary objectives of Innovation Centers include providing support for the independent innovator or entrepreneur, increasing non-Federal investment in research and development, and accelerating the commercialization of innovations (see figure 6).

The Innovation Centers Experiment was designed so that Government support for the Centers would terminate after 5 years. At that time, the viability of the Centers would be demonstrated if they become self-sustaining and if they become models for further efforts to promote innovation and entrepreneurship.

The RDI Program and RANN—initially separate thrusts—have merged, and the Innovation Centers Experiment is now under the aegis of the Industrial Programs area of the RANN Division of Intergovernmental Science and Public Technology.

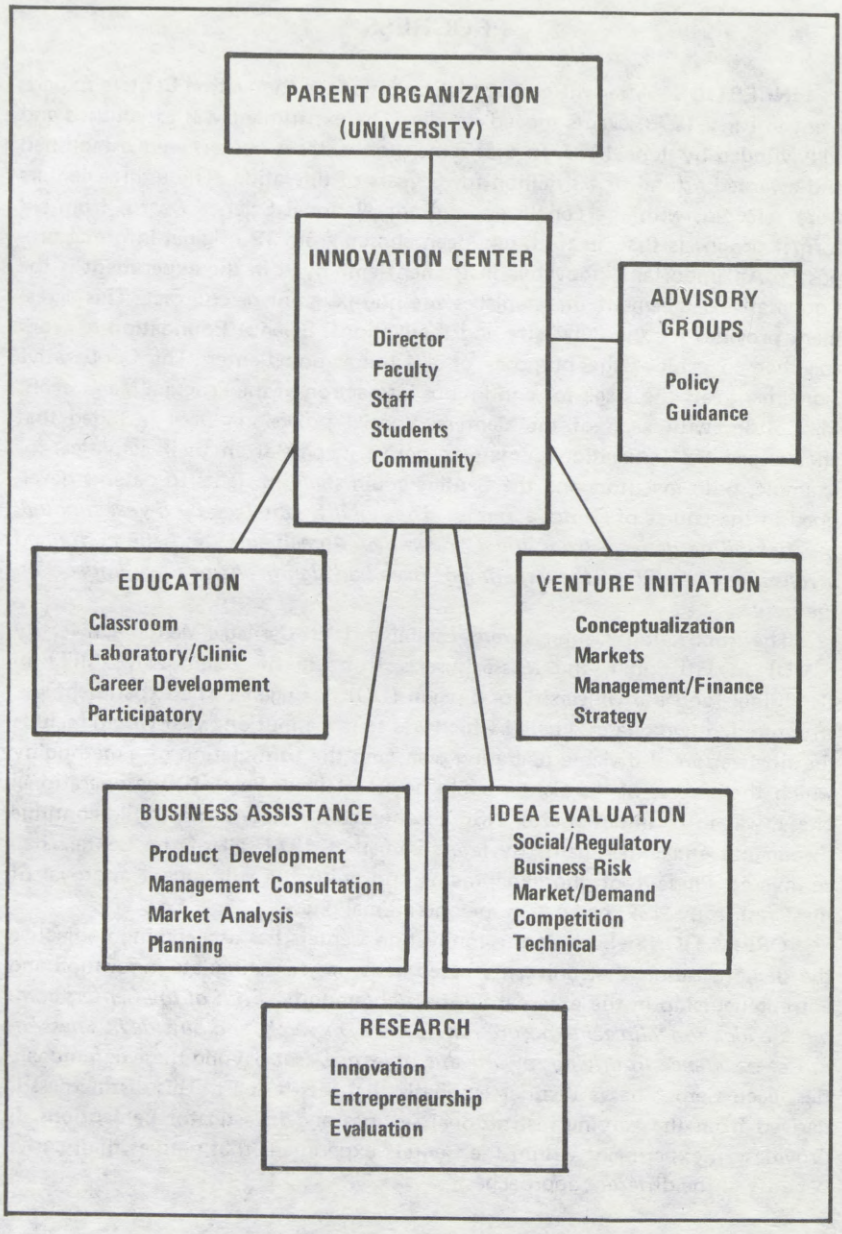



Figure 6. Innovation Center concept.

## PROGRESS

**INCEPTION**—After the conceptualization of the Innovation Centers Experiment in early 1973, events moved rapidly. The experiment was established and fully funded by June 1973. In that same month, three centers were established and awarded a total of $3 million for 5 years of operation. These three centers were selected, with the concurrence of the National Science Board, from six formal proposals that, in turn, had been chosen from 12 original informal proposals. An important innovative instrument employed in the experiment is the Cooperative Agreement that replaces the normal grant or contract. This agreement provides for the university and the National Science Foundation to work together to achieve the purposes of the Innovation Center. The Cooperative Agreement sets the stage for continuous interaction of the Program Manager, R. M. Colton, with each of the Centers. Special provisions were included that encouraged the Innovation Centers to derive income from their activities; for example, both inventors and the Centers could share in rights to patents developed in the course of Center activities. *The stability obtained by 5-year funding, the flexibility derived from the Cooperative Agreements, and the continued involvement of NSF in the experiment have had significant positive impacts on the results.*

The Innovation Centers were established at Carnegie-Mellon University (CMU) in Pittsburgh, the Massachusetts Institute of Technology (MIT) in Cambridge, and the University of Oregon (UO) in Eugene. The experiment was structured in two phases. Phase I which was to last about one year would include the finalization of a viable operating plan, and the formulation of a method by which the success of the Center could be ascertained. Phase II, the operational phase, was to be initiated after NSF acceptance of Phase I and would continue throughout the experiment. By late summer of 1974, all of the Centers had completed Phase I of the experiments and, with the subsequent approval of these results by NSF, had begun the operational phase.

**OPERATIONS**—Each of the Innovation Centers has as a common objective the demonstration that university-based activities can stimulate innovation and entrepreneurship in the external business community. *Each of the Centers combines education, clinical exposure for students, research, and outside business/inventor assistance in driving toward this objective.* But beyond these commonalities, each Center has a distinct emphasis that sets it apart. This distinctness is derived from the varying institutional settings and investigator perceptions. It provides an experiment within the Centers experiment that defines the relative benefits of the different approaches.

**Innovation Center**
**Prof. Yao Tzu Li**
**Massachusetts Institute of Technology**

At MIT, the central purpose of the engineering school-based Innovation Center is to provide a supplemental education program in which various disciplines are linked to enhance the entrepreneurship ability in participating students. The teaching methodology stresses direct participation of students in innovation including the risk-taking and rewards that are inherent to the process. The Innovation Center has two primary branches, the Innovation Education Program and the Innovation Co-op.

The Innovation Education Program provides an opportunity for students, who do not have time to become involved in the "learn by doing" process, to obtain the distilled experience of the entrepreneurial activities. This is centered in five core courses: Introduction to Innovation, Invention, Entrepreneurship, Invention Development Laboratory, and Internship in New Enterprise Development. In the fall of 1976, 104 students were enrolled in these courses.

The Innovation Co-op includes three programs: the Entrepreneurial Development Program, the Industrial Product Development Program, and the Invention Development Program. In the Innovation Center the ultimate goal is to give students the opportunity to follow the entire product development cycle from conception to the marketing of the product. This Entrepreneurial Development Program is a time-consuming and expensive process. Two companies have been founded by this process: Computer Controls Corporation and Hetra Inc. Their products are a computer-controlled heating, ventilating, and air conditioning system, and a precious metals-identifying instrument, respectively.

In the Industrial Product Development Program, product needs are identified by an industrial firm and students and faculty seek innovative products to fill the needs with sponsorship by the industry. Two products resulting from such efforts are a TV tennis game and an automotive ignition system.

The Invention Development Program provides for the evaluation and development of promising inventions. Emphasis is on overcoming both technical problems and on the severe obstacles encountered in reaching the marketplace. An electric guitar, a high performance bow, and a small molecule detector have resulted from this program.

The continued viability of the Center depends on its development of income from royalties, industrial sponsorship, and government contracts and on institutional support. Funding for the Innovation Center is also to be included in the education fund-raising activities of MIT. Over $150,000 in income from royalties and $350,000 in contracts are budgeted for FY 1978. The continuation of the Innovation Center beyond the period of NSF support appears assured.

At the MIT Innovation Center, which is based in the School of Engineering, the focus is on the evaluation and maturation of ideas. In its most recent year, the Center received 139 ideas for evaluation from outside the Center. However, the majority of ideas that receive detailed attention originate with MIT students and faculty because of the desirable direct involvement of the originator with idea development. Ideas are evaluated and developed either in the Innovation

**Center for Entrepreneurial Development (CED)**
**Prof. Dwight M. Baumann**
**Carnegie-Mellon University**

CED operates from an academic base that includes the engineering school, Carnegie Institute of Technology; the Graduate School of Industrial Administration; and the School of Urban and Public Affairs at Carnegie-Mellon University. It is unique among the Innovation Centers in that CED is a separately incorporated non-profit organization affiliated with, and effectively a subsidiary of, the university. Its objective is to encourage and develop entrepreneurial activities through education, research, and support of new venture.

The educational efforts of CED are effected through the academic departments of the university wherein both graduate and undergraduate students have the opportunity to participate. Emphasis is on an engineering design program wherein graduate students participate in actual entrepreneurial activities. In 1975, some 20 faculty and 90 students were associated with these activities.

The focus of CED is on the entrepreneurial process and new business startups. In its first year, three companies were helped: Compu-Guard Security System, Inc.; Sun Publications, Inc.; and Three Rivers Computer Co. By the latter part of 1976, CED had been involved in the startup of a total of 11 companies, the largest of which has an order backlog of $10 million and has 43 employees. Annual sales of the companies exceeded $3.5 million in 1976. In late 1976, CED was involved with eight new business projects and was evaluating many good ideas. It is noted that new business ventures are more limited by a shortage of technological entrepreneurs than of inventors.

The continuation of CED as a self-sufficient Innovation Center, by the operating plan, is dependent on repayment of loans, and on ownership interest in the new ventures. However, the time scale for nurturing an idea to the point where it becomes a business venture and for a new venture to reach a level of profitability to where it can repay the investment is so lengthy that there may be a transition problem at the termination of NSF support. The successes of CED, the early emphasis that it placed on creation of a viable institutional setting, and its vigor in pursuing new opportunities indicate a high probability for continued successful operation.

Education Program or in the Innovation Co-op. In the Co-op, the ultimate product may take any one of three forms: a new company with a new product in which students or former students are the entrepreneurs, a new product developed in response to a specific industry need and with industry support, or a developed invention to be licensed to an existing business. However, overall emphasis is on education with coursework and student instructional laboratories coordinated with the more clinical environment of the Innovation Co-op.

The Center for Entrepreneurial Development (CED) at Carnegie-Mellon University serves as a "maternity ward" for new business startups with a focus on technology transfer through entrepreneurship. It is based in the schools of

**Experimental Center for the Advancement of Invention and Innovation**

**Dr. Gerald G. Udell**
**University of Oregon**

The principal thrust at the Oregon Innovation Center is invention evaluation based on the premise that this is one important way in which universities can stimulate inventors, innovators, and entrepreneurs. To this end, much emphasis has been placed on the development of an idea or invention evaluation system in close cooperation with the Western Inventors Council, over 12 industrial concerns, and a number of universities and agencies. In its most recent reporting year, the Oregon Innovation Center received 244 ideas, innovations, or inventions for evaluation.

In addition to its evaluation activity, a full spectrum of education and entrepreneurial encouragement activities are maintained. In the curriculum of nine courses, 510 students were enrolled in the 1975-76 academic year. Graduate student participation in center activities is increasing. Activities include teaching, consultation, research, and curriculum development.

Many innovations evaluated at the Oregon Innovation Center have been patented. From the 30 or so patents, examples range from portable electric ovens and laser printers to a high rise solar/wind collector. A number of reports have been issued on the evaluating process, and during the latest year four new ventures were formed; for example, one is attempting to commercialize a therapeutic knee exerciser.

The original goal of the Oregon Innovation Center was to be self-supporting from the fees charged for idea evaluation and from venture income or royalties by the end of the NSF-supported experimental period. The experience with the incubation of new ventures has indicated that this is not practical; however, through its performance, a constituency is being developed through which continued support may be derived.

engineering, business, and urban and public affairs. The CED emphasis on entrepreneurship leads to its providing financial services, laboratory facilities, and other resources for university-derived, technology- or research-based new businesses. The university environment is seen as providing a constant stream of potential innovations. CED, through the teaching of entrepreneurship and its study of barriers to innovation, attracts and encourages potential entrepreneurs. When a technological entrepreneur and his idea are considered viable, CED becomes actively involved in the creation of a business. The incorporation of the Center as a nonprofit entity for investing in new enterprises and for sharing in their success is viewed as an essential element in making entrepreneurship an important activity in the academic community.

The plight of the independent inventor is the primary concern of the Oregon Innovation Center. Its academic and educational programs are in the College of Business Administration. Working in close cooperation with the Western Inventors Council, the Oregon Center's outreach extends more to inventors outside of the academic community than do the other two centers. Early emphasis

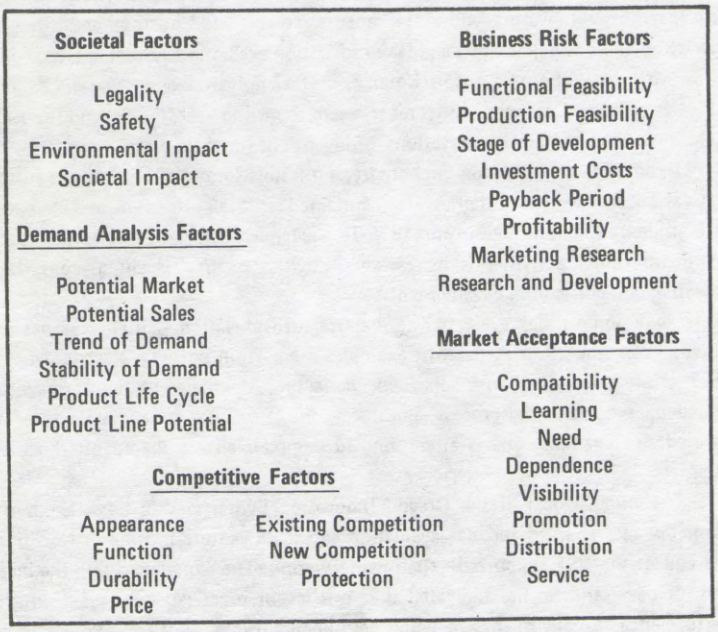



Figure 7. Invention evaluation.

was on the development of an invention evaluation system that identifies ideas that promise commercialization success. For the relatively few promising inventions from the many submitted (244 in latest year), the Oregon Innovation Center offers the inventor assistance at whatever level is required in return for participation in future profits and royalties. Contacts with industry, government agencies, and others are cultivated to help in invention development and commercialization. Thus the largest effort has been invested in development of an effective and efficient means of evaluating new ideas and transferring technology to the end of stimulating inventors, innovators, and entrepreneurs (see figure 7).

The three Innovation Centers are thus operating entities. Some 25 academic courses, 700 students, and 54 faculty members are associated with the Innovation Centers (see the appendix). An evaluation of the progress being made toward the prime objective—increasing the number of students who become successful entrepreneurs—is not yet possible. It will come with time. At this time, the success of the Innovation Centers must be measured in terms of interim products and subsidiary goals. These are presented in the next section.

## PRODUCTS

The Innovation Centers Experiment has obtained visibility, is producing results, and appears at this time to be a success. The nature of the experiment, its broad objectives, and the stature of the universities that host the Innovation Centers by themselves create a positive aura. A firmer substance is being given to this appearance of success by the statistics associated with the experiment—that of students, ventures, inventions, and flow of ideas. Interviews with people who have had contact with the Centers reenforce this finding as do the proliferation of emulators at other universities. But all of this evidence does not really demonstrate the success of the experiment; it only proves that something good is being done. The success of the experiment will only be proven when the entrepreneurship of the student participants is shown to exceed that of a control group. NSF plans to track the participants over a period of several years to obtain this data and thus to measure the effectiveness of the experiment. In the meantime, the interim results can be examined and used.

**EDUCATION OBJECTIVES**—Carnegie-Mellon, MIT, and Oregon were teaching courses in innovation and entrepreneurship before the Innovation Centers Experiment began. During the course of the experiment, the number of students has expanded from 400 to 700 and the number of courses offered each year has increased from 14 to 30 (see figure 8). The courses that are in the curricula are listed in table 1.

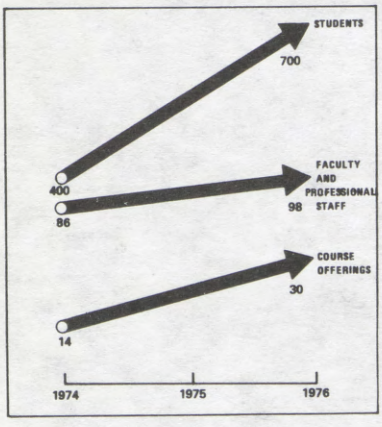



Figure 8. Educational activities of innovation centers are increasing.

**Table 1. Courses Associated With Innovation Centers**

| | |
|---|---|
| University of Oregon | Massachusetts Institute of Technology |
| Small Business Management | Introduction to Innovation |
| Venture Finance | Invention |
| Management and Innovation | Entrepreneurship |
| Entrepreneurship | Invention Development Laboratory |
| Management Research and Development | Internship in New Enterprise Development |
| Applied Innovation I | Invention and New Enterprise Seminars |
| Applied Innovation II | Innovation Project Seminars |
| Marketing Innovations | Marketing New Products |
| | Innovation Workshop for Industry |
| Carnegie-Mellon University | |
| Small Business Problems | |
| Design and Entrepreneurship | |
| Management of Technological Innovation | |
| Engineering Economics | |
| Management Strategy | |

The introduction of innovation and entrepreneurship offerings for students in universities is not without difficulties. The discipline-oriented and crowded curricula in the conventional university departments compete for students and are not receptive to interdisciplinary or nontraditional courses. Dr. Li at MIT has supported the Innovation Education Program with NSF funds and, in the Engineering School, has provided a homogeneous and strong course offering. He has argued eloquently for the important role of these courses as a supplementary education program. Despite an apparent reluctance of other faculty members to encourage students to take the Innovation Education Program courses, enrollment has grown and the innovation curriculum is becoming a permanent university-supported program.

In similar fashion, a strong set of courses in innovation and entrepreneurship has become a part of the curriculum of the College of Business Administration at Oregon. In the latest reporting year, 510 students enrolled in these courses, for an increase of 25 percent over the previous year. At Carnegie-Mellon less emphasis is placed on special courses. The educational objectives are met primarily by the existing curricula of the involved schools.

K.H. Vesper has tracked entrepreneurship education at American universities and reports that upward of 80 schools now offer such courses as compared

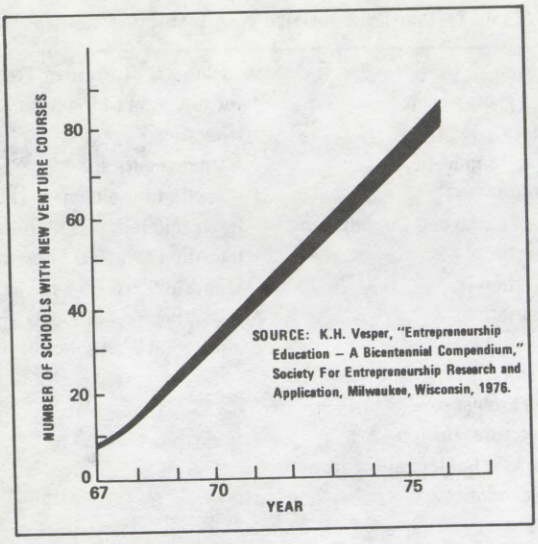



Figure 9. Growth of entrepreneurship education.

to only 10 a decade ago.* (See figure 9.) During the period of the Innovation Centers Experiment, this number has increased by one third. It would be erroneous to ascribe this to the Innovation Centers directly, although there is evidence that many schools have been influenced by the experiment.

**VENTURE INITIATION**—At the beginning of the Innovation Centers Experiment, prior activities at MIT and Carnegie-Mellon had resulted in venture activities, the needs of which were rapidly responded to by the embrionic Innovation Center. Successes were realized.

At CED, for example, a company, Compu-Guard, had been formed in 1972 by two Carnegie-Mellon graduates, Romesh Wadhwani and K. Pribadi. At critical points in its development, Compu-Guard was provided with various types of assistance by CED including a direct loan and help in securing contracts and venture capital. Compu-Guard now has $3 million in annual sales, a $10 million order backlog, and 40 employees including 8 additional Carnegie-Mellon graduates. It manufactures and sells electronic computer-controlled security and energy management systems (see figure 10).

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*K.H. Vesper, ***Entrepreneurship Education—A Bicentennial Compendium***, Society for Entrepreneurship Research and Application, Milwaukee, Wisconsin 1976 (supported by National Science Foundation).



Figure 10. Compu-Guard Personal Communicator that transmits a signal to a central receiver in an emergency.

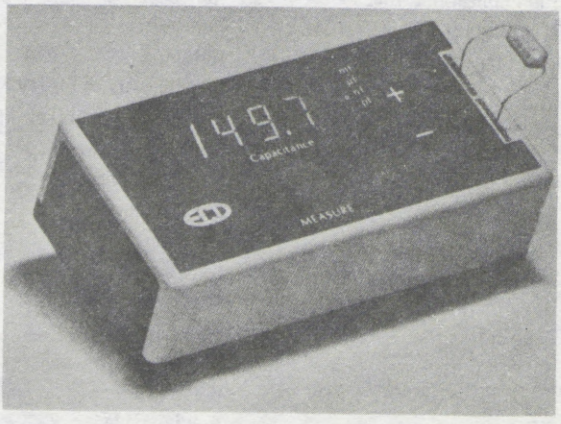



Figure 11. ECD precision autoranging digital capacitance meter.

In a similar fashion, three MIT students formed ECD Corporation in 1974 with its first product being an auto-ranging digital capacitance meter (see figure 11). While the product and its design were not developed in the Innovation Center, ECD President, Richard Eckhardt, gives much credit to the entrepreneurial courses that he took at MIT and to continued contacts with the Innovation Center. Without that help, success would have been achieved much more slowly. Annual sales volume now exceeds $200,000, the backlog is $1,500,000, and the company has expanded its product line to include a minicomputer.

Referring to table 2 that lists the Innovation Center-assisted or incubated business activities that have resulted in sales, one can see that 23 such activities exist. The circumstances by which an Innovation Center was involved with each

**Table 2. Active businesses initiated or assisted by innovation centers**

| Business | Product | 1976 Sales | 1976 Order Backlog |
|---|---|---|---|
| Kemtech, Inc. (Executive Games) | TV Games | $5,000,000 | $ 5,000,000 |
| Transcomm Data Systems Corp. | Timesharing computers | 2,000,000 | |
| Compu-Guard | Security devices | 1,000,000 | 10,000,000 |
| Fisher Stoves, Inc. | Wood burning stove | 400,000 | 1,000,000 |
| Peoples Cab Co. | Transportation | 250,000 | |
| ECD Corp. | Capacitance meter | 200,000 | 1,500,000 |
| Three Rivers Computer Co. | Computer hardware | 175,000 | |
| Sun Publications, Inc. | Newspapers | 135,000 | |
| Transportation Concepts, Inc. | Three wheel car | 117,000 | 2,000,000 |
| Myers Motors, Inc. | Automobile | 69,000 | |
| Computer Controls Corp. | Control systems for HVAC | 50,000 | |
| Peoples Travel, Inc. | Transportation broker | 50,000 | |
| Rehabilitation Equipment, Inc. | Prosthetics sales and service | 30,000 | |
| MBA Consultants | Business services | 20,000 | |
| Klein Corp. | Bicycle framesets | 15,000 | |
| Richards Frames | Wood picture frame | 12,000 | |
| Wrench Knives, Inc. | Knives | 12,000 | |
| Royal Industries | Nite trainer | 10,000 | |
| Redi-Grill | Wine rack | 10,000 | |
| Vectran Corp. | Remote control devices | 10,000 | |
| Graphic Forms, Inc. | Wood printing | 2,000 | |
| SICO | Folding table | – | 50,000 |
| Health Spa, Inc. | | – | 250,000 |
| Totals | | $9,567,000 | $19,800,000 |

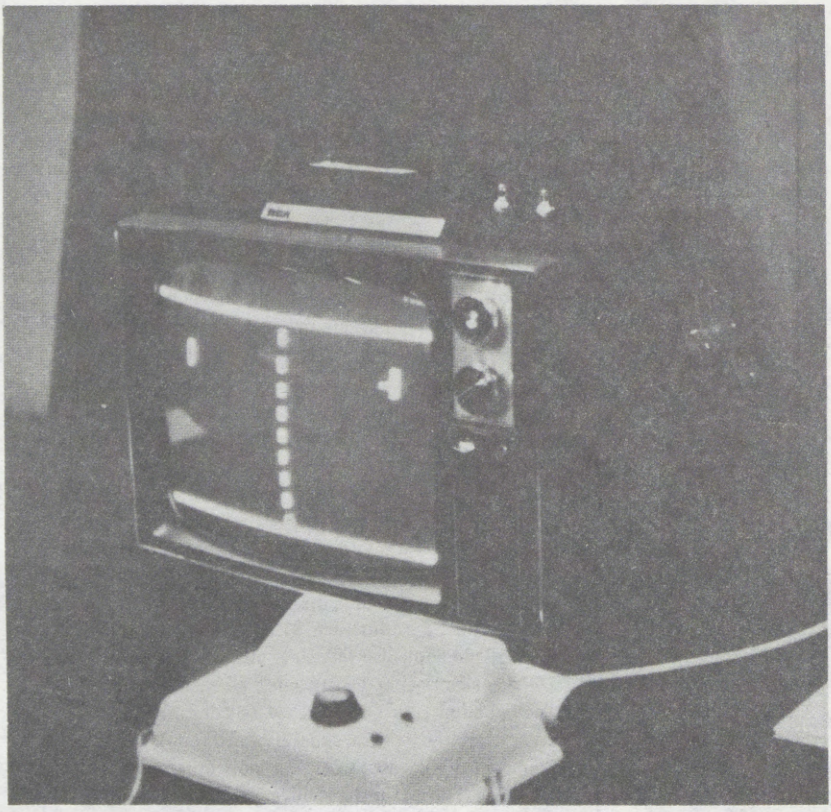


Figure 12. TV game developed in Innovation Co-op at MIT.

venture varies greatly. The first business on the list involving the TV games resulted from the Industrial Product Development Program in the Innovation Co-op at MIT (see figure 12). The product need was brought to the Center by an industrial firm, it was developed by students as part of their entrepreneurial education, and it is now a viable product.

For every business on the list, the Innovation Centers played a key role in their success. Most would not exist had that help not been available.

The total sales and backlog of these businesses in 1976 are shown in table 2. The accumulated total of sales was in excess of $30 million at the end of 1976. Employment of an unsophisticated economic model as described on the following page shows that over $6 million in direct taxes were generated by such sales. This assumes that the products do not displace other production, and does not

**Calculation of Tax Generation by Innovation Center Stimulated Products**

A simple tax generation model has been developed to provide a basis for developing estimates of the impact of Innovation Centers on total tax revenues.

For each dollar of sales by a manufacturing industry, an average of $0.24 is used for employee compensation, $0.03 for indirect business taxes, and $0.09 is property type income (ref. 1). This is the total of the value-added in the manufacturing process. Of the employee compensation, about 13 percent is personal income taxes (ref. 2) or $0.03 per dollar of output. While these allocations are based on older data, the proportions, which are used in the calculations, are relatively invariant with time. The tax rate for property type income is about 50 percent, so that the average total direct taxes per dollar of output in manufacturing is:

$$2.0 \times 0.105 \times \$30{,}000{,}000 = \$6{,}300{,}000$$

As indicated above, however, this represents only the *direct* generation of taxes. Since virtually all industries use the output of other industries in their production, increases in sales in one industry will increase the sales, hence taxes, in other industries. These interrelationships are captured in an input-output table. As an example, the Bureau of Economic Analysis has estimated that the household appliance industry requires a total industrial output of $2.37 for each $1.00 of final sales (ref. 3). This includes not only the $1.00 of the appliance industry, but also $0.25 for basic metals, $0.05 for rubber, $0.06 for electrical apparatus, etc., all except the first of which are counted at least twice but all of which generate tax revenues. Thus, for the appliance industry, it is necessary to multiply tax revenues by 2.37 in order to obtain an accurate estimate of the tax impact of increased sales. For most other manufacturing industries, this multiplier is above 2.0; so, for the Innovation Centers, a conservative multiplier of 2.0 is applied.

For $30 million in sales, the taxes generated are therefore:

$$\text{Taxes/dollar output} = \$0.03 + \$0.03 + \$0.045 = \$0.105$$

This neglects such factors as the tax losses resulting from displacement of other domestic production by the new products, the taxes gained by the personal consumption expenditures of the workers, and other similar factors. It does, however, provide a valid and conservative measure of the tax revenues derived from the Innovation Center-associated ventures.

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**Table 3. Examples of Ideas Being Evaluated**

*Thermalite*—a window insulation scheme for energy savings.
*Music synthesizer*—method for creating music by drawing waveform with hand.
*Automatic tuning device*—a device for indicating the musical note that is being played and how far off standard pitch that it is.
*Traffic sensor*—a capacitive strip sensor that gives number, speed, and weight of vehicle.
*Holding tank flushing system*—a device that facilitates the cleaning, disinfection, and deodorizing of holding tanks on vehicles.
*Mold for utility holes*—a mold to be used in constructing concrete walls to provide holes for passage of utility lines.
*Clay mill*—a machine for mixing potter's clay.
*Mounted levels*—a concept for mounting bubble levels on hand tools such as drills.
*Solar panels*—designed to collect solar heat and to be the southern wall of structure.
*Air cleaner*—a self-cleaning automotive air filter.
*Disposable oxygen sensor*—a sensor for measuring oxygen content of molten steel.
*Mercury switch*—an orientation-independent mercury switch.

account for indirect taxes resulting from personal consumption expenditures by the employees. In any case, this calculation indicates that taxes generated by Innovation Center-associated ventures exceeds the total 5-year cost to NSF of the experiment.

A number of additional ventures are in various stages of development, short of realizing sales. These include Bactex Laboratories that is concerned with the detection and prevention of gonorrhea, Hetra Corporation with a precious metal forgery detection instrument, Fab-tek, Inc., with a therapeutic knee exerciser, and Jesika with a noninvasive oximeter.

**IDEA EVALUATION**—A large need exists for credible evaluation of ideas and inventions. This was evidenced during the first year of the Innovation Centers Experiment when more than 500 ideas were brought to the Centers. This number has been increasing with a majority of the evaluations performed at the Oregon Center which emphasizes this function. Examples of the nature of these ideas, from all three Centers, are listed in table 3. Contacts with submitters of these ideas have established that a high level of satisfaction is being achieved, although only relatively few ideas are recommended as being worthy of continued development.

This particular aspect of the Innovation Centers Experiment has received considerable attention,* because of the need for such evaluations and the apparently inadequate service provided by commercial firms.

*See for example, "Whatever Happened to Independent Inventors?" ***Science News***, vol. 110, pp. 60-62, 1976; and D. Carlinsky "Inventions, The Uphill Road to Riches," ***Money***, June 1976, p. 66.

**RESEARCH**—There are four levels of research associated with the Innovation Centers Experiment: (1) that which comprises the experiment and its objectives, (2) that which is concerned with the organization and operational modes of each of the Centers, (3) that which deals with the invention, innovation, and entrepreneurial processes, and (4) that which is concerned with the maturation of specific ideas, inventions, innovations, or ventures. Aside from the fourth level which is a key part of center activities, the research agenda has developed slowly. At the first level, data collection instruments have been developed for evaluation of the success of the Centers in meeting their stated objectives. The substantive analysis results can only be developed in the future.*

The organizational or operational modes of the Centers are each different and are being continuously evaluated and adjusted to optimize performance. Relative productivity of the different modes cannot be assessed because of the variances in environment and emphasis, and because only early results are available.

Research by the Centers in the invention, innovation, and entrepreneurial process is developing. Examples of specific reports are shown (see figure 13 and appendix). The numbers of published papers (about 20), talks (about 25), and special reports (about 6) are increasing as the efforts achieve maturity. It is found that most of these research topics, and related dissertations, are derived through the business schools rather than the engineering schools.

**UTILIZATION**—A study of the utilization of the Innovation Centers Experiment gave it a high rating.† A total of 50 RANN projects were included in the utilization study, and comparisons were made among these on the basis of user responses, progress toward stated goals, and investigator opinion. In the utilization study on the Innovation Centers Experiment, 18 interviews with entrepreneurs, students, venture capitalists, government officials, industry executives, and others who have had contact with, or should know about, the Innovation Centers revealed a supportive constituency.‡ In table 4, the factors that influenced this support are listed. *Even though the study revealed that barriers are still being encountered (e.g., lack of acceptance as full partners in the academic community, questionable financial stability beyond the period of the experiment, ventures that fail, and inventions that do not find a market), it concluded that each of the centers was in its own way demonstrating the efficacy of innovation centers in an academic environment.*

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*R.M. Colton and G.G. Udell, "The National Science Foundation's Innovation Centers—An Experiment in Training Potential Entrepreneurs and Innovators," *J. Small Business Management*, vol. 14, pp. 11-20, 1976.

†R.M. Burger and M.F. Massoglia, *Utilization Analysis, RANN Research Products*, Research Triangle Institute, Research Triangle Park, N.C. 27709, May 1977.

‡R.M. Burger and M.F. Massoglia, *RANN Utilization Experience, Report to the National Science Foundation, Case Studies 32 through 41*, Research Triangle Institute, Research Triangle Park, N.C., November 1976.

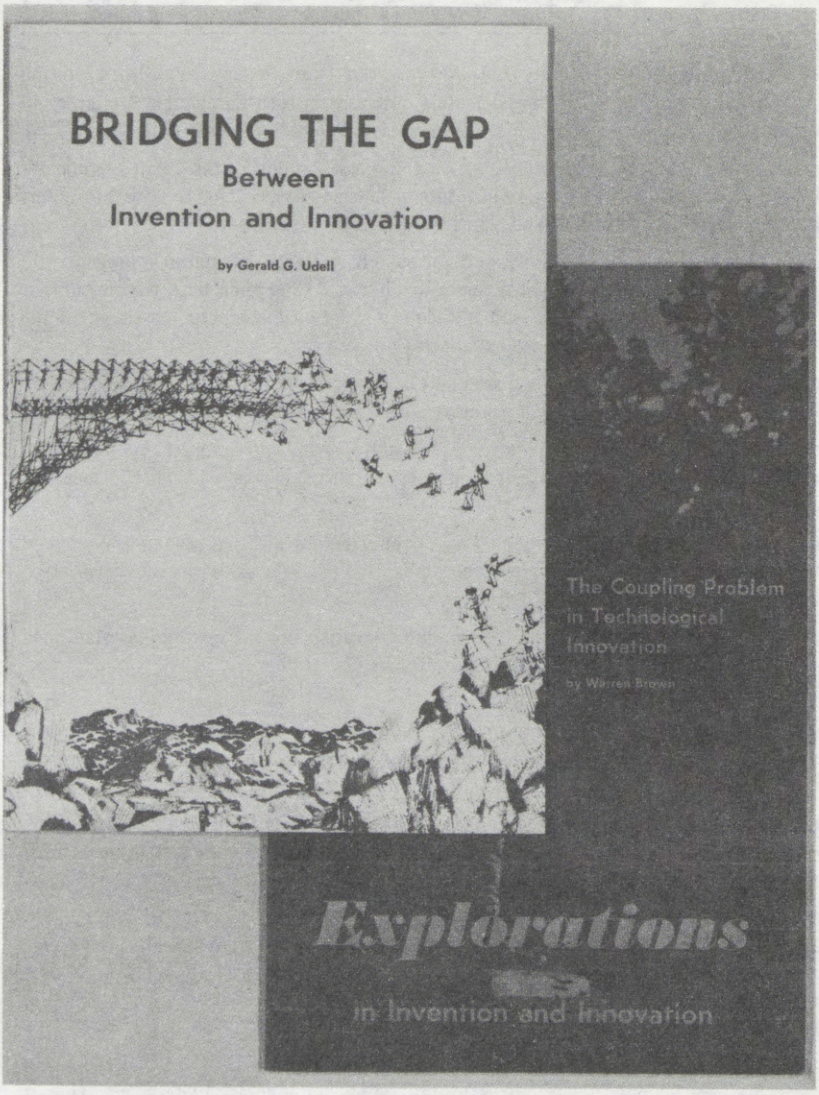



Figure 13. Research reports.

**Table 4. Factors That Influence Utilization of Innovation Centers Experiment**

*The experimental nature of the program*—emphasis is on testing hypotheses on the education of entrepreneurs and on innovation, although in each Center this is interpreted differently.

*The well-defined experiment duration*—knowing that NSF support of the Centers terminates in 5 years places emphasis on creation of future income and causes some to view the Centers as transient perturbations in the educational structure.

*The multiobjective structure*—the hierarchy of objectives creates options in approaches and products and permits commendable program flexibility. At the same time, the measures of performance are not well defined and it becomes easier to "march to the sound of the drums" rather than follow a reasoned experiment protocol.

*The caliber of the directors*—through selection of strong Center Directors, a strong measure of enthusiasm, competence, and zeal permeates the Centers and bodes well for their success.

*The importance of the subject*—innovation and entrepreneurship are in the national spotlight, thus the Innovation Centers Experiment benefits from a large receptive audience, but must bear the burden of detailed scrutiny.

*The quality of the work*—each of the Centers can enumerate significant accomplishment and an apparent concordance of support from those served. The early victories have aided greatly in attracting recruits to the Centers.

*The resistance to change*—as innovations in the education process countering established academic patterns, the Centers meet with resistance just as does any interdisciplinary program in a disciplined structure.

*The block funding*—the initial commitment to full funding of the programs has been important in allowing the Centers to obtain institutional status and to avoid the resource dissipation associated with renewal processes and the accompanying uncertainties.

*The program management*—although minor irritation was voiced relative to the documentation required for the experiment evaluation, no significant faults were attributed to NSF management in response to inquiries on this subject. All evidence points to an effective, flexible, and constructive approach to Center supervision by NSF.

*The liberal patent policy*—the agreements permitting the Centers to develop through patents (and other means) income that supports present and future operations, are a significant factor in the experiment design and are apparently an innovation in government policy that could have far-reaching effects.

*The nature of venture capital*—in the business world, venture implies levels of risks and rewards that are beyond the resources of the Innovation Centers Experiment. Thus it appears that the ventures being undertaken must be considered as small-scale laboratory experiments, and recognition must be given in the research to the factors involved in full-scale ventures.

## PROGNOSIS

The Innovation Centers Experiment is still in progress. It ends in 1978. Examination of the products and effects of the experiment indicate that it is successful. The spawning of new ventures from a university base, the demonstration that entrepreneurs can be nourished in the academic environment, the development of innovative products that are suitable for production, and the development of pragmatic evaluation methods for new ideas are directly responsive to the need of universities to become more relevant to society while maintaining their traditional educational and research functions. Already, at least eight other major universities are in the process of establishing Innovation Centers based on the NSF model. Effects are spreading to the Small Business Administration where university-based small business development centers are being conceptualized for encouraging entrepreneurship. For example, committee hearings have been held in the Senate on S. 972, the Small Business Development Center Act of 1977.

Each of the Centers has established a supportive constituency; at Oregon, the independent inventor; at Carnegie-Mellon, the local business community; and at MIT, the university and participating industries. All three Centers are attracting the attention of government mission agencies for their ability to respond to specific needs.

The ultimate effect of the Innovation Centers will be to gain an enduring status as important components of major universities and through them to stimulate the regrowth of invention, innovation, and entrepreneurship in the American economic system.

> ". . . But the full panoply of engineering is innovation, including invention, the design of a new product, production of a prototype model, specification testing, market testing, the devising of new manufacturing procedures, the writing of instruction books, the selling of the product, and economic studies to insure that all of the effort is not misplaced. The ultimate test is its financial success: the production of something that people will buy.
>
> Most of our university activity, even in engineering schools, focuses on research and gives short shrift to the other elements in the innovation process. . . .
>
> Eric A. Walker
> President Emeritus, The Pennsylvania State University
>
> from "University Research—Is It Paying Off?" *Research Management*, XX, p. 7, May 1977

# APPENDIX

## ADVISORY GROUPS

### MIT – Advisory Board of the Innovation Co-op

Professor A. Douglas Carmichael . . . . . MIT
Mr. Paul V. Cusick . . . . . V.P., MIT
Mr. Bernard Gordon . . . . . .Pres., Analogic Corp.
Dr. Arthur Kantrowitz . . . . . .Dir., Avco-Everett Research Division
Professor Francis F. Lee . . . . . MIT
Professor Yao Tzu Li . . . . . MIT, Ex-Officio
Dr. Howard McMahon . . . . . .Senior V.P., Arthur D. Little
Professor Eric von Hippel . . . . . MIT
Mr. Joseph Yamron . . . . . .V.P., Northrop Corp. Electronics Division

### Carnegie-Mellon – CED Community Advisory Board

Leland Hazard, Chairman of the Advisory Board, Professor Emeritus of the Graduate School of Industrial Administration of Carnegie-Mellon University, and former Vice-President and Director of Pittsburgh Plate Glass Company;

Walter Blenko, a senior partner in Baskin, Boreman, Wilner, Sachs, Gondelman, and Craig law firm;

S.W. Herwald, Vice-President of Engineering, Westinghouse Electric Corporation;

Hiram Milton, President of the Regional Industrial Development Corporation;

Robert Pease, Executive Director of the Allegheny Conference on Community Development;

Robert C. Todd, Jr., Vice-President of Pittsburgh National Bank

### Oregon – Western Inventors Council

John Auld
Bob Bennet
James Bjork
Floyd Dickson
Lee Eggers
John Gregor
Roger Hunt
Waldo Inman
Al King
Mel Lindley
Doug McCool
Greg Page
Roger Poe III
Linda Pompel
Nancy Schoelerman
Sidney Smart
Max Wales
Robert Walker
David Whitbread
Myra Willard
Ray Willard
Patricia Williams
Walker Williams

# APPENDIX

## FACULTY

### MIT – Innovation Education Council

| | |
|---|---|
| Professor A. Douglas Carmichael | Ocean Engineering |
| Professor Ernest Cravalho | Mechanical Engineering; Associate Dean for Educational Programs, School of Engineering |
| Professor Woodie C. Flowers | Mechanical Engineering |
| Dr. Ogden H. Hammond | Chemical Engineering/Energy Lab |
| Professor Walter M. Hollister | Aeronautics & Astronautics |
| Professor David G. Jansson | Aeronautics & Astronautics/ Innovation Center |
| Professor Francis F. Lee | Electrical Engineering |
| Professor Yao Tzu Li | Aeronautics & Astronautics/ Innovation Center |
| Professor George C. Newton, Jr. | Electrical Engineering |
| Professor Eric A. von Hippel | Management |
| Professor David N. Wormley | Mechanical Engineering |

### University of Oregon

| | |
|---|---|
| Dr. Gerald G. Udell | Director |
| Dr. Roman R. Andrus | Research Associate |
| Dr. Leslie L. D. Shaffer | Faculty Associate |
| Dr. Kenneth Ramsing | Faculty Researcher |
| Dr. Gerald Albaum | Faculty Researcher |
| Dr. Warren Brown | Faculty Researcher |
| Dr. Del Hawkins | Faculty Researcher |
| Dr. Paul Swadener | Faculty Researcher |
| Dr. Bruce Woodson | Business Development Coordinator |
| Dr. James Reinmuth | Acting Dean, CBA |

### Carnegie-Mellon University

| | |
|---|---|
| Professor Dwight M. Baumann | Mechanical Engineer, CED |
| John R. Thorne | Industrial Administration |
| Professor Charles H. Kriebel | Industrial Administration |
| Professor David P. Rutenberg | Industrial Administration |
| Professor Arnold R. Weber | Industrial Administration Dean, Graduate School of Industrial Administration |
| Professor William W. Cooper | Public Policy Dean, School of Urban and Public Affairs |
| Professor Herbert L. Toor | Dean, Carnegie Institute of Technology |

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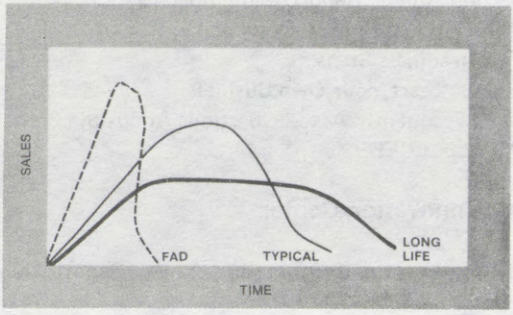
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# Incubators for Entrepreneurs

**Experimental innovator/entrepreneur hatcheries at universities put venture and vision together to nurture embryo enterprises.**




**Product life cycles.** Budding innovator/entrepreneurs need to know along which curve an invention falls.

Philip Doucet, at the age of 26, is president of Computer Controls Corporation in Cambridge, Massachusetts. His expanding company, which builds energy-saving, computerized, heating and cooling control systems, was incubated at the Massachusetts Institute of Technology. The concept grew out of an MIT entrepreneurship course project. The product was financed through MIT and developed in a university laboratory. Indeed, if it weren't for the school's "moral, financial and managerial support," declares Doucet, "we wouldn't be here."

It's much the same story for 28-year-old Joseph Sigel who publishes three thriving biweekly newspapers in Pittsburgh. His idea of establishing a paper, distributed free to students and supported solely by advertising, emerged from an entrepreneurship class at Carnegie-Mellon University (CMU). Says Sigel, "The course forced me to come up with the right questions and find out all the facts."

The two youthful entrepreneurs are alumni of pioneering, university innovation centers that the National Science Foundation has been funding since 1973. The centers evolved from a program the Foundation set up six years ago to identify and test various incentives for stimulating technological innovation. There was (and still is) rising concern that the pace of innovation in the United States was lagging. At the same time, it was becoming more and more difficult to launch a new business. Venture capital was scarce. Many markets were dominated by giant corporations. And fewer potential entrepreneurs were willing to take on the risks involved in starting a new enterprise.

Innovation and entrepreneurship are closely linked. Innovation—introducing something new or novel—entails risks. Without entrepreneurs who are willing to assume risks, innovations wouldn't reach the marketplace. Indeed, it has been this combination of innovation and entrepreneurship that has given the American economy much of its dynamism. Accordingly, the National Science Foundation set out to determine whether or not there are ways of generating not only more innovation but also more entrepreneurs.

The basic concept was the experimental innovation center, a university-based center where technological innovation could be stimulated and entrepreneurial instincts and skills nurtured. Engineering and business students would couple a formal training in innovation and entrepreneurship with first-hand experience in a novel laboratory setting where what they'd be learning could be put into practice. The final result could be a new product or even a new company.

Three universities, already somewhat involved in entrepreneurship training, were chosen initially to carry out the innovation center experiment. Each had a different emphasis. The Massachusetts Institute of Technology concentrated on undergraduates and the generation of new ideas. Carnegie-Mellon focused on graduate students and the creation of new enterprises. The University of Oregon sought to bridge the gap between invention and innovation by singling out a vexing problem faced by

independent inventors: the difficulty of getting new concepts objectively and reasonably evaluated. The key in every instance was to be the involvement of students. The $3 million of NSF support was spread over five years, both to provide continuity and to give the centers a chance to become self-supporting.

### A hatchery for start-ups

Dwight Baumann, a mechanical engineer, designed Carnegie-Mellon's Center for Entrepreneurial Development as "an incubator, a hatchery for new company start-ups." The nonprofit Center, affiliated with the university, provides fledgling entrepreneurs not only technical and managerial assistance but also hard-to-obtain seed money: loans (in kind) of up to $40,000 worth of materials and services.

Baumann tried to create what he calls "a studio without walls, an association of people, loosely related, who communicate with each other and can get help when they need it. We find people who are good breeding stock, so to speak, bring them together and develop a laboratory in which we can watch things happen and make them happen." The aim was to encourage a cross-fertilization of ideas and skills among the talented and motivated individuals in an atmosphere that stimulates innovation. This process, Baumann believes, is a key factor in the spontaneous proliferation of the technology-based companies that, in the last few decades, sprang up around such university towns as Boston, Palo Alto and Ann Arbor.

The core of CMU's graduate course in entrepreneurship, in which students learn about patent law, market research, business analysis and so on, is the project approach. Baumann is quick to note that this emphatically is not a case study method. "A case has already happened in real life and the results are known," he explains. "A project is something that hasn't yet happened. And the instructors and students have the common goal of seeing how it'll turn out."

Outside inventors or innovators are brought in to describe their concepts. The students then determine potential markets, competitors, manufacturing costs and whatever else is needed to bring the idea or product to the marketplace; they draw up what is termed a "business plan."

More often than not, the class consensus is negative. For example, a new technique for producing copper wire was



**Spawning new enterprises.** Dwight Baumann works with fledgling entrepreneurs in starting up new businesses.

Cal-Mar Studio

judged to be a nonstarter because of declining copper demand.

But sometimes these outside projects turn into something more than class exercises. CMU medical researcher Richard Longini developed an instrument that optically monitors the oxygen content of a patient's blood. Most of the students concluded that there was only a limited market for the invention. However, one student, David Reese, disagreed. After graduating, he formed a company with Longini and borrowed $40,000 in development-aid from the Center. (All Center investments are "in kind" and are carried, and repaid, as business debts.) The device has been further refined and is now undergoing final premarket testing at a local hospital. The potential market is indeed limited —but, they believe, the achievable limit is about $15 million.

In another instance, two CMU alumni (then working for a Westinghouse subsidiary) showed the class their improved concept for the remote control of locomotives and cranes. The students produced a comprehensive business plan which, as one of the inventors, Tom Hutton, puts it, "forced us to get our act together and gave us a psychological push." The two quit their jobs, borrowed their $40,000 in services from the Center and recently went into production. They already have more than $250,000 in orders.

The final test for the students comes when they split into groups and develop their own projects. A few have already evolved into going businesses. Joe Sigel, for example, noted that, between CMU and the nearby University of Pittsburgh, some 46,000 students were concentrated in a small area. Why not a give-away student newspaper supported by advertisers? "I knew nothing about the newspaper business," he recalls, "so I had to talk to publishers and find out all the facts. As a result, I got more and more interested and decided to take a chance."

Less than half of the 12 new ventures spawned with the help of the Center came out of the entrepreneurship class. "The concept of the studio," remarks Baumann, "doesn't require that anyone has to take the course." Indeed, the Center's most successful offspring thus far was started by two foreign students who never attended the course. Romesh Wadwhwani, an Indian, and Krishnahadi Pribadi, from Indonesia, were doctoral candidates at CMU when they came to Baumann five years ago with an idea for a wireless "wrist radio" security system. Signals from the radio, carried to a computer by a building's electrical wiring system, identified the nature and location of the problem.

With Baumann's help, the two won a sizable government development contract and formed a company, Compu-Guard. The Center invested $40,000 in services and later helped the tiny enterprise get several million dollars of outside venture capital. Compu-Guard is now manufacturing computerized building security and energy management systems, employs 90 people (including eight CMU graduates) and expects 1978 sales of $4.3 million. Wadwhwani makes it clear that the Center's financial and managerial assistance was initially crucial to his thriving company's survival and growth.

Other possible new ventures, as Baumann puts it, "are in the womb." They include such products as a new theater lighting system, a fetal heartbeat monitoring device, a pocket oscilloscope and a computer-linked taxicab meter that calculates passengers' fares before the trip. All, or perhaps none, of these and other ideas may evolve into new businesses. That's the unique aspect which makes the CMU (and MIT) approach different from those of other schools offering entrepreneurship courses—the tantalizing prospect of, as Baumann puts it, "going all the way and starting a new company."

So far, some 300 students have taken the CMU course. Baumann estimates

that not more than four or five percent of this admittedly select group can "make things happen." He says another 80 percent aren't ready to go out on their own but "come to understand what an entrepreneur is all about." Perhaps as important, a number came to the realization that the life style, uncertainty and risk involved in entrepreneurship isn't for them.

Admittedly, the process of creating innovators and entrepreneurs is still somewhat mysterious. "Creativity," says Baumann, "is that act done by others which we wish we'd done ourselves. By definition, the creative process is improbable and there aren't any recipes, because recipes define probable acts. That doesn't mean we can't deal with the creative element scientifically. And it doesn't mean we can't find out how to build an incubator for new businesses. Because we don't know all about embryology doesn't mean we don't have chickens."

**Like a teaching hospital**

Undergraduates are the focus of MIT's Innovation Center, where the emphasis is more on the process of innovation than on new venture start-ups. Students can take courses in innovation, invention and entrepreneurship and serve as interns in new enterprise or invention development programs. In addition, there's the "Innovation Co-op" which, says Yao Tzu Li, the aeronautical engineer who heads the MIT Center, "functions like a teaching hospital to expose students to the real-world activities of an entrepreneur."

As at CMU, a student with an invention or concept deemed commercially promising by the Co-op Advisory Board might be provided services, treated as a loan, for as much as $40,000 for further development. The student innovator not only can use the university's extraordinary research and technical facilities, but can also draw on what the Center's brochure calls "the breadth and depth of expertise available at MIT."

The resulting product may be licensed to a company, with the Center and student developer (or developers) sharing royalties on a 65/35-percent basis; the Co-op may approach a company to finance development of a promising student invention; sometimes the Co-op helps a student or ex-student set up a new venture to manufacture and market some innovation.

In a number of cases, the initiative has come from the outside: a company seeking the Center's help to solve a problem or develop a product idea. The Center

**ACTIVE BUSINESSES AND NEW PRODUCTS INITIATED OR ASSISTED IN DEVELOPING BY INNOVATION CENTERS 1977-1978**

| BUSINESS | PRODUCT LINE | 1977 SALES (ACTUAL) | 1978 SALES (PREDICTED) | CENTER AFFILIATION |
|---|---|---|---|---|
| Fisher Stoves, Inc. | Wood Burning Stove | $ 2,000,000 | $ 2,500,000 | Oregon |
| Cornerstone Systems Inc. | Manufactured Building Systems | 500,000 | 750,000 | Oregon |
| Thermo-Cycle, Inc. | Energy Circulation Systems | 300,000 | 500,000 | Oregon |
| Myers Motors, Inc. | Low-Fuel Consumption Vehicle | 230,000 | 400,000 | Oregon |
| Wrench Knives, Inc. | Specialty Knives | 200,000 | 300,000 | Oregon |
| Transportation Concepts, Inc. | Low-Fuel Consumption Vehicle | 30,000 | 2,000,000 | Oregon |
| SICO | Hideaway Folding Tables | 15,000 | 15,000 | Oregon |
| Moonstreet, Inc. | Etched Glass | 15,000 | 30,000 | Oregon |
| Richards Frames,Inc. | One-Piece Wood Frames | 12,000 | 15,000 | Oregon |
| Graphic Forms, Inc. | Printing on Wood | 10,000 | 120,000 | Oregon |
| Transcomm Data Systems, Inc. | Timesharing Computer | 3,000,000 | 4,300,000 | CMU |
| Compu-Guard, Inc. | Load Management/ Energy Conservation | 3,040,000 | 4,000,000 | CMU |
| Three Rivers Computer, Inc. | Computer Hardware | 300,000 | 500,000 | CMU |
| Peoples Cab, Inc. | Transportation/Ride Sharing | 275,000 | 300,000 | CMU |
| Sun Publications, Inc. | Periodicals/Newspapers | 175,000 | 250,000 | CMU |
| Vectran Corp. | Industrial Remote Control Devices | 124,000 | 500,000 | CMU |
| Rehabilitation, Inc. | Prosthetics | 31,000 | 38,000 | CMU |
| Bactex, Inc. | Medical Tests | — | — | CMU |
| Jessika Oximeter | Medical Tests | — | 80,000 | CMU |
| — | Fetal Heartbeat Monitor | — | — | CMU |
| ECD Corporation | Meters/Computers | 2,000,000 | 2,000,000(1) | MIT |
| Computer Controls, Inc. | Energy Control Systems | 100,000 | 400,000 | MIT |
| TRI-VI, Inc. | 3-Dimensional Display | — | — | MIT |
| Hetra Corp. | Precious Metal Detection | — | — | MIT |
| Semtel, Inc. | Current Limiting Devices | — | — | MIT |
| ATF, Inc. | Electronic Games | 20,000(2) | — | MIT |
| Koss Corp. | Radio Headsets | — | — | MIT |
| — | Robot Guidance Control | — | — | MIT |
| MCI | Anesthetic Techniques | — | — | Utah(3) |
| Teramatek | Sodium Sulfur Battery (Alumina) | — | — | Utah(3) |
| Terratek | Geological Drilling & Exploration Techniques | 4,000,000 | 4,500,000 | Utah(3) |
| Evans & Southerland | Computer Simulation Systems | 8,500,000 | 10,000,000 | Utah(3) |
| Kenway (Eaton Corp.) | Computerized Warehousing | 37,000,000 | 40,000,000 | Utah(3) |
| Soundstream | Digital Sound Reproduction Systems | — | — | Utah(3) |
| Totals | | $12,377,000(4) | $18,998,000(4) | |

Percent change vs 1976—+30%

(1) Product line sold (2) Licensing fees only (3) Businesses were initiated prior to NSF funding
(4) Totals exclusive of Utah items

Source: NSF Industrial Programs Office

will enlist student engineers with the necessary skills, and the firm will supply the development funds. The Center and the students involved will later divide any returns under a licensing and royalty agreement with the company.

For example, a local businessman told an invention class in late 1974 about the need for an improved method of testing the purity of gold and silver. (The Government was soon to permit the free sale of gold in the United States; the existing system was expensive and time-consuming.) Five students in the class took up the challenge. With $20,000 in development funds from the businessman, they built a device that cut dramatically the cost of assaying gold. They then joined the businessman in forming a company (and recently sold out their shares).

The most lucrative instance of this sort of arrangement involved a low-cost television tennis game invented by a Ghanian student. A games manufacturer heard about the idea and supplied $35,000 to a team of Innovation Center students to produce a production model. Sales during 1975 and 1976 hit $3.5 million before the business folded under the pressure of lower priced competition. But the Center and student developers still received $50,000 in royalties.

**Invention + enterprise = . . .**

Some inventions (and new enterprises) have emerged from the Center's innovation and entrepreneurship classes. Philip Doucet's Computer Controls Corporation is a prime example. His idea of using microprocessors to control heating and cooling systems was a course project. The concept was developed in MIT labs with a $40,000 in-kind loan from the Co-op. And his company was formed with advice and counsel from Co-op professionals.

Last year, MIT freshman Edward Berlin came up with the concept of a device for creating a three-dimensional display from two-dimensional tomographic X-rays, a problem being attacked from several directions (see "Adding a Dimension," *Mosaic*, Volume 7, Number 6). Co-op manager Lamar Washington arranged for a group of neurosurgeons and neurologists to finance further development of the invention at MIT and to form a new company with the youthful student inventor.

Richard Eckhardt, who started a firm called ECD to build new electronic measuring devices when he was graduated by MIT, says, "The training I got at the Innovation Center was invaluable in terms of knowing what to expect. You encounter problems before you have to experience them. And if you know what's going to happen, you're one step ahead of the game."

A number of new inventions, such as a device and method for destroying the Herpes simplex virus and a more efficient, low-cost solar collector, are still in the embryo stage. Meanwhile, the fertile young minds in the Center's various classes continue to generate fresh ideas —everything from an advanced water faucet valve to a self-programming, computer-controlled machine tool. "By introducing the product development and marketing phase at an early stage in an engineer's career," says the Center's brochure, "the Innovation Center hopes to produce more innovative engineers with an appreciation for their role *vis-a-vis* society."

Indeed, the crux of innovation, according to Li, is "to first perceive a need and then interface with technology. We teach the entire process, including setting up companies. What we're trying to do is create more ideas and develop a sharper eye for matching ideas with downstream problems."

His estimate agrees with Baumann's: Perhaps only five percent of the 600 or so students who've gone through the Innovation Center possess the particular combination of talents and drives to become innovators and entrepreneurs. But, Li adds, "They all see this experience as opening up their horizons . . . . We let them know what's going on in the world."

Although neither Baumann nor Li make a big point of it, they themselves have a significant impact. Both are not only dynamic personalities but are also innovative entrepreneurs who've started and run successful ventures. Thus, they and other faculty entrepreneurs, such as John Thorne at CMU and Frances Lee at MIT, serve as role models for the students.

Recent CMU graduate George Sepelak says that "being around Dwight Baumann certainly opened my eyes, seeing him take risk after risk. Anyone who's worked with Dwight would probably go out on his own, given the opportunity." MIT senior Sue Kayton, a member of the group that formed the precious-metals detector company, feels the same way about Li. "Being around people like Dr. Li and others, you pick things up," she declares. "They really know what's going on. Y. T. is an inspiration." Although she plans to work for some company for a few years, Kayton insists that, "If I see an opportunity, you bet your boots I'll start my own business."

**A critical eye**

The University of Oregon, the third base of the NSF experiment, focuses on problems facing the independent inventor. Gerald Udell, head of Oregon's Experimental Center for the Advancement of Invention and Innovation, points out that only two or three of every 100 product ideas ever reach the market. The rest fall by the wayside for a variety of reasons—too expensive to produce, lack of market appeal and so on. The list seems endless.

For the inventor, the crucial question is whether his idea is worth developing. Is it commercially feasible? Many independent inventors pay commercial invention evaluators as much as $3,000 for answers. Yet, studies show that fewer than one inventor in 10,000 earns enough from the invention to cover the adviser's fee.

Explains Udell: "There was no place inventors could go for independent advice during the *initial* stages. But now we have a system for making evaluations." The Oregon Center's computerized evaluation system has been refined and improved over the past few years. The actual cost of evaluating an invention at the Center during the experiment has been about $150, but a user pays only $50 (NSF funds make up the difference).

A fledgling inventor first sends in a confidential disclosure form that includes all the information on his concept or invention. The Center then assigns as many as five specialists to make the evaluation. Panelists are drawn, in varying combinations, from among members of the Western Inventors Council (a private, nonprofit group of professionals in various fields, affiliated with the Center), academic authorities and, when they can make a contribution, business graduate students.

Each evaluator fills out a form that covers 33 criteria crucial to the commercial success of an invention. The criteria are wide ranging, covering everything from legality, durability and existing competition to environmental impact, potential markets and distribution. For each of these criteria, the evaluator marks one of five responses. For example, under "safety" the evaluator can check: "Very unsafe, even when used as intended; Unsafe under reasonably foreseeable circumstances; Relatively safe for



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careful, instructed users; Safe when used as intended, with no foreseeable hazards; Very safe under all conditions, including misuse." The forms are keyed into the computer, and the resulting printout represents a consensus evaluation of the invention.

The printout, sent to the inquiring user, lists each criterion with its consensus evaluation. An accompanying 86-page booklet explains the significance of every criterion (a page reference is listed on the printout for each). The printout, Udell explains, "gives reasons why an idea is or isn't feasible. The evaluation gives the inventor an insight into where his invention is at and what he might do to correct deficiencies and improve it. Perhaps just as important, it gives him some insight into the innovation process."

About 85 percent of the inventions submitted are judged to be not worth developing further, for a variety of reasons (the most common: marketing problems). Such a negative report can, according to Udell, "save you from investing a great amount of time and money." For instance, he recalls a proposed electric car with a generator hooked to each wheel so the batteries would recharge while the vehicle was moving. "It was a perpetual-motion machine," says Udell. "Here was an example of an individual who could have spent a great deal of money. We recommended he not go any further." Another inventor had already spent more than $10,000 for a prototype heater to be attached to the stove of a recreational vehicle, before he came in for an evaluation. "The product was clearly unsafe," Udell points out. "It should have been killed at the idea stage; if he'd come to us originally, we could have saved him a lot of money."

Those inventions that seem promising (fewer than 15 percent) can move to a second stage. An inventor can sign a royalty agreement with the Western Inventors Council in return for further assistance. Staff and students may define markets, research production costs, analyze consumer buying patterns and so on. In some cases the Center may help ar-



**Incubated and hatched.** Among the projects stimulated through the university-based innovation/entrepreneurship centers are (from top) a digital taxicab meter being tested on a workbench, Joe Sigel shown laying out the front page of his *Pittsburgh New Sun* and Philip Doucet (right) and a colleague at Computer Controls Corporation.

Carnegie-Mellon University, Cal-Mar Studio; Massachusetts Institute of Technology

range financing and licensing.

Udell, for example, tells of a device for training bed wetters that he calls "a superbly developed product, better than anything on the market." The Center found a company interested in marketing the invention and set up a licensing agreement for the inventor.

One of the most promising new developments was a unique construction system using prefabricated, insulated, four-by eight-foot panels. According to Udell, the system can reduce the cost of materials in an average house by 20 percent and cut construction time dramatically. The Center is providing the inventor, a small building contractor, with marketing research, business planning and leads for additional venture capital.

Thus far, more than 25 inventions have reached the marketplace with the Center's aid, including a safety device to prevent scalding in showers and bathtubs, a three-wheeled car and a table that attaches to the wall and folds flat when not in use.

Some 800 evaluations were completed in 1977, compared to about 300 the previous year. In 1978, Udell expects the number to rise above 1,200. Because of the rapid increase in volume, only a small percentage of the promising ideas can get research assistance. "We've had to be much more selective," says Udell.

### A better mousetrap

Now that the five-year experiment is winding up, the question remains: Can innovation and entrepreneurship be taught and nurtured? Even though all indications are positive, the final returns are not yet in.

There will always be some to argue that innovators and entrepreneurs must be born—they can't be made. Those involved in the National Science Foundation experiment disagree: Carnegie-Mellon's John Thorne maintains that by "taking those students with the drive, motivation and need for independence, as well as other attributes, and showing them what the game is really like, we'll see a higher percentage of them start their own thing after four or five years than if they hadn't been exposed."

The Denver Research Institute will be following up to see if Thorne's thesis bears up. As part of the experiment, alumni of the MIT, CMU and Oregon programs are being tracked over a five-year period. They'll be compared to control groups of similar students (some of whom have taken entrepreneurship courses) from Case-Western, Southern Methodist and either the California Institute of Technology or California State Polytechnic University. The question: Will more students who've gone through the MIT, Oregon and CMU innovation centers become entrepreneurs when matched against their peers from other schools?

Robert Burger of North Carolina's Triangle Research Institute, who's done two reports for NSF on the centers, has already come to some tentative conclusions. "If a person has an innate capacity," he says, "and the center brings it out, it's the same thing as creating it in him. It doesn't make any difference in the final result if the capability was originally there or not. But if it weren't for the center, some of those who have or will become entrepreneurs probably would not have done so. So, it's a moot point whether the center creates it in him or releases it."

By a number of measures, there's little doubt that the experiment has been a success. Some two-dozen new businesses have been created with aid and counsel from the innovation centers. More than 75 new inventions have been spawned by the centers, and thousands of inventions have been evaluated. Based on total sales of the new companies at the end of 1976, estimates were that over $6 million in direct taxes had already been generated, more than twice the NSF investment in the experiment.

Student enrollment at the three centers has also grown, from 400 to over 1,000. Burger also points to what he calls "the wake that's been created in the academic world as a result of the experiment. You find people in other schools adopting it in one form or another." Indeed, the number of schools offering innovation and entrepreneurship training has grown from 10 to more than 80 over the past decade. Some were surely inspired by the NSF experiment. Innovation centers like those at MIT, Oregon and CMU have already been established at the University of Waterloo in Canada and, with NSF aid, at the University of Utah. Other universities, and the states of Ohio, Michigan, Washington, New Jersey and Maine, may follow suit.

Everyone involved agrees that the innovation center concept is itself an innovation and a legitimate subject of research. "It's not clear yet what science will evolve," says Baumann. "We're still at a clinical stage. We're still trying to see what happens and understand in a general way what the ingredients are that make the incubator work.

"The data aren't all in yet, and we still have to find out whether what we've observed in potential entrepreneurs will have a correlation with the anecdotal stories we'll hear five years down the road."

Marsha Grad of the Denver Research Institute has been doing some of the analyzing of the centers for NSF, and she's convinced that the "things that have come out of this experiment are really exciting. We've seen the ability of disciplines to get together—with engineering students acquiring business skills and then spinning off new ventures or innovations. That's really important. Also, the fact that an entrepreneurial activity has existed within a university environment for nearly five years is really monumental. It's clear now that this kind of activity can flourish at a university."

The other test of the experiment is whether such activity can survive financially; can innovation centers such as those at MIT, CMU and Oregon support themselves without any Government seed money? The answer seems to be a resounding yes—and no. The MIT center, with a combination of industry development grants, product royalties and private gifts, seems likely to make it. The situation at CMU is less clear; much future support depends on the success of new ventures spawned by the Center. A number look promising, but most are still too young to provide much return. As for Oregon, director Udell says flatly, "If we can't get further financing, such as Federal funding, the Center will close."

Whether or not the existing centers survive, the seed planted by the five-year experiment may be sending down roots. Under one suggestion, Federal funds would be made available to the states to, among other things, aid universities in setting up small business centers. It is also being proposed that additional university-based innovation centers, such as those in the NSF experiment, receive continuing support. Under another proposal, innovation centers alone would be singled out for Government aid.

Nobody can foresee the ultimate outcome of such efforts. But, as Dwight Baumann concludes, "For a long time we've focused on creating jobs; it's time now we focused on the other side of that equation: creating employers." •

*The projects discussed in this account were part of an experiment designed and supported by the Industrial Programs office of the National Science Foundation.*

PB 290407

# DRAFT REPORT

# ON

# DIRECT FEDERAL SUPPORT OF RESEARCH & DEVELOPMENT

A Draft Report of the Advisory Subcommittee on Procurement and Direct Support of Research & Development of the Advisory Committee on Industrial Innovation established as part of the Domestic Policy Review

December 21, 1978

Notice: This report represents the views of the Subcommittee on Procurement and Direct Federal Support of Research and Development of the Advisory Committee on Industrial Innovation, an advisory committee convened by and reporting to the Secretary of Commerce. The views of the Subcommittee do not necessarily represent those of the Department of Commerce or any other agency of the Federal Government.

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See also report dated 16 Jan 79, PB-290 408. Draft report of the Advisory Subcommittee on Procurement and Direct Support of Research and Development.

This report represents the conclusions of the Panel on Direct Federal Support of Research and Development to stimulate innovation. The concern with direct Federal support of R&D is primarily one of determining whether there are actions which the Federal government can take that involve R&D line items in the budget which can influence the innovation rate. The panel identified three sectors from which one could expect a disproportionately accelerated rate of innovation provided that institutionalized mechanisms are created to provide the essential coupling between the generation of R&D and its utilization in new products, processes or test methods. These three sectors are respectively: the university environment, small venture businesses, and trade associations. The panel considers why each such sector lends itself to a boost in innovative capacity and proposes budgetary and institutional mechanisms to effect this.

KEYWORDS: *Technology innovation, *Financing, *National government.

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## FOREWORD

A domestic policy review of industrial innovation is being conducted as a result of President Carter's concern for the status of industrial innovation in the United States. This review is being directed by the Industrial Innovation Coordinating Committee, chaired by Secretary of Commerce Juanita M. Kreps.

An Advisory Committee on Industrial Innovation has been established that will bring to bear the views of business and industry, organized labor, the public interest, and the academic community expert on the subject. The subcommittees created under this Advisory Committee are examining a wide array of federal programs and policies that impact upon industrial innovation.

This Draft Report on Direct Federal Support of Research and Development was prepared by the Advisory Subcommittee on Procurement and Direct Support of Research and Development under the chairmanship of Dr. Jack E. Goldman, Group Vice-President and Chief Scientist of the Xerox Corporation. The subcommittee, composed of representatives of the business and industrial community, has focused on Procurement and Direct Support of Research and Development issues and their impact on industrial innovation.

The public portion of the domestic policy review will culminate in a series of seven public symposia to be held in January 1979. This report, together with those of the other advisory subcommittees, will form the basis for presentations and discussions at the symposia. The moderator for these symposia will be Dr. Jordan J. Baruch, Assistant Secretary of Commerce for Science and Technology.

Following is the membership of the Subcommittee on Procurement and Direct Support of Research and Development, as well as the symposia schedule.

ADVISORY COMMITTEE ON FEDERAL POLICY

ON INDUSTRIAL INNOVATION

Advisory Subcommittee on Procurement and Direct Support of Research and Development

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DOMESTIC POLICY REVIEW OF INDUSTRIAL INNOVATION

Public Symposia Schedule

| Subcommittee on - | Date (1979) |
|---|---|
| Procurement | January 15 |
| Direct Support of Research and Development | January 16 |
| Environment, Health, and Safety Regulations | January 17 |
| Regulation of Industry Structure and Competition | January 19 |
| Economic and Trade Policy | January 22 |
| Patents | January 24 |
| Information | January 25 |

Location: All symposia will be held in the U. S. Department of Commerce Auditorium on the first floor of the Main Commerce Department building (entrance on 14th Street between Constitution and Pennsylvania Avenues, N. W.)

Statement of Interest

This document represents a draft of the report from the Advisory Subcommittee on the Direct Federal Support of R & D. This report is being reviewed by the members of the subcommittee and is, therefore, subject to modification. It is provided at this time as preliminary information for the convenience of those involved with the Domestic Policy Review.

INDUSTRIAL INNOVATION ADVISORY COMMITTEE

Report of Advisory Subcommittee
on Direct Federal Support of
Research & Development

J.E. Goldman - Chairman

## INTRODUCTION

This report represents the conclusions of the Panel on Direct Federal Support of Research and Development to stimulate innovation. The Panel did not attempt to deal in-depth with the relationship between R&D and Innovation. Many earlier studies have covered this subject and in the final analysis it is not an established casual relationship between R&D and innovation that motivates consideration of the subject but a recognition that within the universe, the state and the firm, there is a correlation between the rate of innovation and the total R&D effort. Our concern with direct Federal support of R&D is then primarily one of determining whether there are actions which the Federal government can take that involve R&D line items in the budget which can influence the innovation rate.

The Federal R&D budget is a large agglomeration of line items in the budgets of a large number of government departments and agencies intended to serve a wide variety of purposes and constituence. It touches all disciplines, a variety of social and national needs and deploys all the institutional mechanism to carry out the R&D demands. The magnitude of the national expenditure has not been of concern to the panel but rather in what way does the nation's R&D effort catalyze innovation as distinct from discovery, invention or application of known methods. In this respect, the panel believes that while the knowledge-base that government supported R&D (particularly R) enables is being continuously expanded, there may be distortions in directions toward which the knowledge is focused and perhaps an imbalance in the institutional support where the knowledge is created. The essential problem, therefore, is one of coupling the knowledge base to the needs and opportunities for technological innovation.

The panel identified three sectors from which one could expect a disproportionately accelerated rate of innovation provided that institutionalized mechanisms are created to provide the essential coupling between the generation of R&D and its utilization in new

products, processes or test methods. These three sectors are respectively: the university environment, small venture businesses and trade associations. We consider why each such sector lends itself to a boost in innovative capacity and propose budgetary and institutional mechanisms to effect this. As an addendum, we considered the problem of managing this from the government's point of view and while we make no recommendations for major change in the government's method of budgeting and managing its R&D resources, we call attention to the ONR experience which the panel believes is the government's most successful experience in managing Research and stimulating innovation. The panel also recommends that Federal government agencies be encouraged to accept and fund unsolicited proposals which the government has shied away from in recent years but are often a source of innovative ideas for products and processes.

## I UNIVERSITY-INDUSTRY RELATIONS

The principal basic research resource in the United States resides in the university community. Seventy percent of that research is funded by the Federal government. It is a $4 billion resource and represents a significant fraction of the total R&D commitment of the U.S. and a major portion of the R part of it. But the panel senses that there has been an ever widening gap between the university and industrial communities and as a result that huge resource is not being tapped for its innovative potential since promotion of research to innovation has been largely the province of the industrial community. One of the factors evidencing this diminution of the influence of university research on innovation is the paucity in today's environment of growth of new innovative business such as populated the Route 128 and Palo Alto communities in the fifties and sixties which was largely influenced by the university communities in those two georgraphical locations. The panel feels that some Federal funding of university research should be such that cooperation with industry will be stimulated and promote closer coupling of some fraction of university research to industry without compromising the fundamental tenet that university research be publishable and freely available.

Any proposal to improve the coupling of university research with industry should meet the following criteria to qualify for Federal support:

1. University and industry (either an individual firm, a group of firms, a professional society, or a manufacturer's association) will identify the program for funding selected research problems at the university, including criteria for personnel interchange if desired.

2. A program will be partially funded by the proposing industry so that the industry will have a stake in the selection and performance of the research or exchange program.

3. The university participants retain publication rights and patent rights.

4. A program should in general extend for a period of up to three years to overcome initiation difficulties and to provide some stability to university programs.

5. Matching funds formulae should be developed to allow participation of industrial firms of any size and such a way that:

   - Industry would have an incentive to participate, e.g., part of matching funds supports the same project that industry funds.

   - University would have an incentive to participate, e.g., part of matching funds be used for undesignated university research but in the same or related generic area.

   - There be no decrease in current level of industrial contributions to universities for non-contract research and development, something less than $75 mil. Where industry wishes to fund university research but retain proprietary rights, industry could continue to fund under contract.

   - Total matching fund, to all universities under these new programs should be in the order of 10-20 percent of universities' total research budget.

   - Small companies receive higher Federal matching formulas to give them more leverage with universities and therefore encourage universities to perform research for small business.

It is proposed that the government encourage the direct coupling of university research to industry needs by giving matching grants to be recommitted to research activities at one or more universities. The industrial sponsor would be completely responsible for the selection and performance of the university research, which will assure better usage of successful results. All results of this research would become public knowledge through publications or patents of the university. Two funding alternatives are discussed in the following sections.

Funding - Tax Credits

Under the tax credit scheme a participating university would be funded directly by the industry involved. The industrial sponsor would receive partial government reimbursement depending on his company's size. This would be done through a tax credit, or if no taxes are due, a tax credit carry forward. Tax credits would vary with the size of the companies and there would be an upper limit in the amount a company may claim. The system can be so structured to forestall companies from curtailing their own R&D activities in order to take advantage of this incentive which is intended to favor universities and university-industry coupling.

The tax credit approach has the advantage of removing Federal bureaucracy from the allocation process. It suffers in that passage of tax credit legislation would be extremely difficult. While still preferable to our panel in the long term, the following transition funding mechanism seems easier to implement.

Funding - Matching Grants

Under this funding scheme the industry would initiate a research and/or education program at the university and would so advise the government which would automatically provide the university Federal matching funds.

Experience of the Plastics Institute has shown that dollar for dollar matching does not stimulate more industry contributions to university basic research. To fully satisfy Criteria 5 and increase industry-relevant research by approximately $300 mil., the matching formula must be greater than dollar for dollar. In fact, if industrial contributions are in the order of $50 mil., $6 Federal dollars per industrial dollar would be required. The panel seems to feel this is too large a matching formula for political acceptability.

Programs involving a single company/university pair and likely to terminate after the three-year period should be funded on a sliding scale. This provides more matching to small companies to give them more leverage with universities. The following table is illustrative:

| Company R&D Expense | Federal Matching Funds: Corporate Funds |
|---|---|
| $ 10K | 10:1 |
| 100K | 5:1 |
| 7 mil | 2:1 |
| 10 mil | 1:1 |
| 100 mil | 1/2:1 |

Multi-company programs, which should be encouraged, may require larger Federal matching ratios for seed money. But as such programs mature Federal support ratios should decrease. Successful programs would likely continue without Federal support: unsuccessful ones can die.

Because of limits on appropriated matching funds, control of Federal funds could be exercised by rejecting applications after the fiscal year's funds are committed. A subsequent section titled "Evaluation" suggests a simple mechanism that would be appropriate for this purpose as well.

Benefits

1. Provides "seed money" for fundamental research studies of a longer range nature that cannot be included in most industrial research programs.

2. Expands the technical exchange and understanding between people in universities and people in industry in areas beyond a specific project, through the personal interaction of those involved.

3. Provides more balance and a broader base toward the industrial needs of the future both in education and technology.

4. Involves minimal governmental overhead expense in the execution of this program.

5. Assures results significant to industry, as no company would contribute their money and time to projects of no value. (Note: This does not mean that every project will result in an industrial product or process. Negative answers preventing going down unsuccessful paths are frequently just as important.)

6. Permits individual project decisions to be made by those directly involved.

7. Provides an increased base of university publications and patents of potential interest to many industries.

8. Provides rapid response to proposals which will aid in the stability of university planning.

9. Reduction of anti-business, anti-free enterprise attitudes of academic and the career choices of young people.

Evaluation

To provide a basis for subsequent evaluation, industry would signify their intent to initiate a new Federally supported university program by submitting a one-page summary sheet to a designated Federal evaluating agency indicating the purpose of the program, the cooperating university and the total amount of funding. The industry and university would submit annual progress reports and a final report of the outcome of their activity. The evaluating agency could follow up as they see fit and desirably could publish a directory of on-going research based on these one-page summaries.

## II. INCENTIVES FOR TECHNOLOGY-BASED VENTURES

There is a body of knowledge and experience supporting the hypothesis that smaller enterprises are disproportionately the source of technological innovations. It is not our purpose in this report to go into the reasons for this other than to postulate a greater propensity for risk taking on the part of small business. It is further postulated that the economic effects of inflation, cost of money, pay-back time, poor access to capital, weak market understanding, and inability to cope with escalating requirements of regulatory and other government or consumer initiated demands, have had negative impact on small business risk-taking to an even larger extent than the impact on large business. Whatever the reasons, the net result is explicit: innovation is down in general and small business contributions are down by an even greater percentage.

It is, therefore, appropriate to consider preferential incentives to small business that would restimulate its traditional inclination toward innovation. The weaknesses of smaller business are more glaring and need buttressing in a period of declining innovation. An ancillary consequence of some form of artifical stimulation of innovation is to challenge existing large effective firms already competent and resourceful in innovation techniques to respond to the emerging new product and process competitors. Rational analysis by the large firm of its loss in revenue and market share from standing pat will lead to its intensified commitment to proprietary innovation. This enhancement of large firm innovation on its own resources is a multiplier of the national benefits from direct federal R&D support to small innovative enterprises. Existing large ineffective firms, unskilled in innovation techniques, will suffer market displacement as new products and less costly processes emerge with growing market leadership by the smaller innovator. Either the ineffective firms will learn to deploy their resources to innovate effectively or they will decline towards failure. Both outcomes are benefits to the U.S. economy from direct federal R&D support.

The panel was unable to agree on a single mechanism appropriate to this narrow but reasonably well defined constituency. However, there are a sufficient number of prototypical solutions that have been successful in other segments of the economy to warrant consideration for applicability to this sector.

1. A National Advisory Committee for Technology patterned after the original National Advisory Committee for Aeronautics that played such a dominant role in moving the U.S. civilian aeronautical capability from poor fifth among developed countries at the outbreak of World War I to primacy in the post World War II era. The pattern then which can be considered relevant now is for a commission composed of appropriate senior representatives of government, academia and industry which would be chartered to establish national goals, policy guidelines and success criteria for technological innovation enhancement in the U.S. and either directly or through sub-committees undertake financial sponsorship of R&D in qualifying small firms carrying such support through prototype, engineering model and pilot plant stage on a cost sharing basis with the company.

2. An institution similar to the F.H.A. to make low interest loans to qualifying small businesses in support of innovative proposals.

3. Federal sponsorship of State programs not unlike the Agricultural Experimental Activities in the State land grant colleges.

III. SUPPORT OF R&D ON GENERIC TECHNOLOGY

1. Direct Federal support, together with industry, of research, development, and dissemination to the U.S. industry of new technology, generic to process or product innovation in wide spectra of industries, should be strengthened and recognized as Federal policy. It should have the following features:

a) Development of a coordinated network of Cooperative Technology Centers (centers of excellence) in various fields of generic technology, distributed throughout the U.S. (e.g., at universities, associations, institutes) strategically located to provide opportunity for maximum coupling with industry.

b) Conduct, at each of these Centers, of research and development of new generic technology in the field of excellence -- technology needed by industry to accomplish process or product innovation.

c) Dissemination to, and assistance in utilization by appropriate U.S. industry of such technology, wherever it originates in the world, including economic studies to evaluate potential return on investment from implementation of the generic technology by appropriate industry.

d) Planning and policy-type guidance of the research, development and dissemination programs of each Center by an associated Working Group made up primarily of representatives from interested industry, but with representatives of the university or college and of the Federal government also participating, and making use of the neutral ground of appropriate engineering societies for organizing and serving as secretaries for these Groups.

e) Planning, policy-type guidance and coordination of the overall Cooperative Technology Centers activity, on a national scale, by a Cooperative Technology Council, again made up primarily of representatives from industry, but with representatives of universities, colleges and the Federal government also participating, for organizing and serving as a secretariat for this Council.

f) Directed emphasis and priority to be given, in the local and national planning, guidance and coordination, to research, development, and dissemination activities particularly pertinent to the needs of small companies and trade impacted, technology impacted, regulation impacted, resource impacted, or disaggregated industries.

g) Funding for the Centers, and of the overall programs, should come jointly from industry and the Federal government. In particular, the Federal funding should be used:

(1) To initiate the overall program;
(2) As seed money for early, high risk research and development of new, advanced generic technology;
(3) to help attract industry funding into such research and development programs as early and as fully as possible; and
(4) continually to assist the Centers in their process of dissemination and transfer to industry of new generic technology, wherever it originates in the world. Use of the Federal procurement process to stimulate or accelerate such transfer should be included in appropriate cases.

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2. Since the Cooperative Technology Centers activity could start small and gradually evolve to cover all fields of generic technology, one initial area of activity would be that of manufacturing technology. The focus in this field should be on the still incipient generic technology of computer integrated manufacturing -- harnassing the computer to optimize and automate manufacturing fully from product design through final inspection -- as a technology in which the U.S. is rapidly falling behind the rest of the world and as one having by far the greatest potential for economic and social benefit, and for enhancing the international competitiveness of U.S. industry, if properly researched, developed and then utilized. Cooperative Technology Centers (centers of excellence) should be established in this field, developing R&D and dissemination programs for such areas as computer aided design (computer graphics), computer optimized production planning, computer optimized production planning, computer optimized production control, computer automated manufacturing equipment and systems, computer controlled in-process inspection and quality assurance, computer automated assembly and robotics.

Here the appropriate engineering society for organizing and serving as secretariat for the Working Groups associated with these Centers would be the Society of Manufacturing Engineers. Appropriate first year Federal funding would be $15 million.

APPENDIX

INDUSTRY COMMENT CONCERNING
OFFICE OF NAVAL RESEARCH

In the meetings of the Industrial Advisory Subcommittee on Direct Support of R&D, the Office of Naval Research has been mentioned repeatedly as a very successful example of federal funding of R&D.

To try to understand the "ONR phenomenon", some historical accounts have been evaluated and discussions have been held with ONR personnel. This brief study leads to the following tentative conclusions:

1. ONR is clearly an example of successful direct funding of R&D by a federal agency.

2. ONR provides in addition an excellent example of successful management of a basic research program; an example which is applicable to industry as well as to government agencies.

The main reasons for ONR's success as a funding agency is its relative freedom from elaborate procedures for submitting proposals and its rapid decision-making process. These reasons were probably even stronger in the past, because ONR has also become more bureaucratic with age, but ONR still seems to be unique in its ability to appraise proposals and make funding decisions quickly. Another unique feature of ONR is the branch-office system (Boston, Chicago, Pasadena, London, and Tokyo) which provides listening posts with proximity to key contractors. This partly decentralized organization certainly contributes to total effectiveness.

The main historical message of ONR is that it illustrates very good management of a basic research program. In trying to understand this fact, one quickly becomes aware that the classical elements of successful basic research management were all present in ONR's history, some of them as a result of straightforward good management. The reasons which stand out are:

1. ONR's management has always had a good understanding of the needs of their customer (the Navy).

2. At the same time, they have been able to maintain a necessary isolation from the everyday operational problems of their customer.

3. They operate with a minimum of bureaucratic constraints.

4. ONR has been managed by competent, confident scientific experts.

5. They have an effective review process; thorough, but not too frequent.

6. They also fund and manage successful applied research (e.g. towed SONAR array technology). This gives ONR a sensitivity to the total R&D process which enhances its performance on basic research.

When one examines the output of ONR's program over the last 30 years it is obvious that widely applicable results have emerged (atomic time standards, metallurgy of titanium and molybdenum, long-term freeze preservation of blood, the lithium battery, computer-aided instruction, etc.). The project selection has clearly been very good. The approach of funding enough projects to insure an adequate level of success has also been used very skillfully.

A historical point of interest is that ONR initially was the only federal funding agency for research. This meant that although the program always reflected the needs of the customer (the Navy), in the initial years it covered a very broad spectrum of scientific disciplines. Over the years, responsibility for some of these scientific disciplines was transferred to new agencies and ONR's range was narrowed. However, I believe the project selection today still has high potential of delivering broadly applicable results beyond the specific needs of the Navy.

In summary, ONR represents an impressive example of basic research management. The effective and efficient management of basic research is one of the most difficult challenges in R&D management. A study of the ONR example is recommended to any organization facing that challenge.

STATEMENT OF DR. L. R. LAWRENCE, JR., DIRECTOR, TECHNICAL DEVELOPMENT, MECHANICAL TECHNOLOGY, INC.

Mechanical Technology Incorporated (MTI) is a technically oriented company that was founded with the objective of transferring high technology to products. This basic corporate objective has placed MTI in the front lines and trenches of trying to achieve industrial innovation. It is from this perspective that we have sought to bring to the attention of policy makers in Washington the current constraints to technical innovation. Therefore, MTI participated on the Advisory Committee on Industrial Innovation and is taking this occasion to comment on the "National Technology Innovation Act of 1979" (S. 1250) and President Carter's Industrial Innovation Initiatives.

We would like to reflect first upon our own observations of the industrial innovative processes and then upon the findings of the subcommittee of the Industrial Innovation Committee in which MTI participated.

MTI has been involved in a number of product innovation assessments recently. In some of these, MTI was the potential manufacturer and, in others, a potential licensor. In all these activities, we examined the decision to commit or not commit resources with a quantitative business venture analysis. Very few of these activities showed a potential for a profitable return. If we adjusted the investments and profits for the risks involved, fewer still would show an acceptable return. In general, a higher expected return can be realized on government notes than on industrial innovation. It is not surprising then, that the current generation of professional managers do not generally allocate corporate resources to innvoation. Most product innovations show profits that are too small, investments that are too large over too long a time, and risks that are too high. A national industrial innovation act should address all these points.

While we agree with the basic findings and recommendations of the Advisory Committee on Industrial Innovation, we feel that its focus is primarily upon the innovation process related to mass-produced consumer products. An ad hoc subcommittee submitted its findings relative to the needs and requirements of what may legitimately be termed the "process" portion of industry. This report is enclosed as Attachment A. The recommendations include: (1) the federal involvement in large-scale innovative process demonstrations to reduce the private sector risk to acceptable levels; (2) the reconciliation of the conflicting, confusing and exploding regulatory reuirements; and (3) financial incentives to make the rewards of innovation worth the risks.

Specific comments upon the actions recommended in S. 1250 and in President Carter's initiatives are presented in tabular form in Exhibit 1. A general comment and observation is that the problems related to industrial innovation are extremely broad. The type of role the government can play in the broad area of industrial innovation can be indicated by the activities it can take in the narrower issue of innovations in energy productivity as shown in Exhibit 2. The President's program goes much further towards addressing the broard industrial innovation issues; but where S. 1250 and the President's program overlap, the S. 1250 reccommendations appear better.

It is extremely gratifying to see that the problem is being recognized and addressed. Even though the steps may not be as comprehensive as we would like, movement by the federal government will create a momentum in the right direction. We, in the private sector, will try to increase the momentum until the U.S. is, again, the industrial innovator.

## Exhibit I — Industrial Innovation Recommendations

| Problem Area | S-1250 Recommendation | Administration's Recommendation | Comment |
|---|---|---|---|
| General Economic Climate | Not Addressed | Not Addressed | "Probably no single factor would have a more beneficial influence on innovation than bringing inflation under control." Dr. F. Press' statement of October 3, 1979. |
| Federal Advocacy for Industrial Innovation | Office of Industrial Technology<br>Industrial Technology Review Panel | Subcommittee on Industrial Innovation<br>Presidential Award | S-1250 recommendation has more substance than other recommendations. |
| Information Transfer | Not Addressed | Center for Utilization of Federal Technology<br>Foreign Technology Information<br>Restructuring Patent Office Information | Indexing and translating foreign industrial research would be good.<br>Interviewing foreign visitors seems to be a waste of time.<br>Making the patent office information accessible to the scientific community would be good. |

## Exhibit I — Industrial Innovation Recommendations (Cont'd)

| Problem Area | S-1250 Recommendation | Administration's Recommendation | Comment |
|---|---|---|---|
| Information Creation | Centers for Industrial Technology | Cooperative Technology Centers<br>Industry — University Cooperation<br>Coordination of Regulatory Compliance R&D by OMB | Federal role in basic or generic technology development should be high since industry cannot justify this type of research.<br>Industry involvement at a minimal level is needed in all programs to keep focus and to avoid the "ivory tower" syndrome.<br>Federal involvement in compliance research is viewed with suspicion by industry; particularly if the R&D agency is also the regulatory agency.<br>The funding levels of S-1250 are more definitive. |
| Federal Regulations | Not Addressed | Various Actions Including Regulation Reform Act of 1979 (S-755) | A move needed to increase innovation. |

## Exhibit I — Industrial Innovation Recommendations (Cont'd)

| Problem Area | S-1250 Recommendation | Administration's Recommendation | Comment |
|---|---|---|---|
| Patent System and Policy | Not Addressed | Uniform Federal Procurement Rules Regarding Patents<br>Improve Patent Office Procedures and Cost Allocations<br>Court of Patent Appeals | Does not address the question of background patent rights.<br>Does not address the question of the dimunition of the value of a patent. |
| Venture Funds — Public Sector — | Not Addressed | NSF Small Business Innovation Program<br>Corporations for Innovation Development<br>ERISA Rule Changes To Allow Venture Investment<br>SBIC Allowed to Coinvest<br>Small Business Participation in R&D Funds | Does not address the basic question of innovation profitability.<br>Does not address problems of doing contract R&D for the government in terms of bidding, funding delays, etc. |

## Exhibit I — Industrial Innovation Recommendations (Cont'd)

| Problem Area | S-1250 Recommendation | Administration's Recommendation | Comment |
|---|---|---|---|
| Government Procurements | Not Addressed | Various Actions | Government procurements should encourage innovation and energy conservation. This is a good area for action. |
| Anti-Trust Policy | Not Addressed | Review by DOJ and FTC of Cooperative R&D Programs | Legislation may be needed due to the independent actions of regulators. |
| Demonstration Programs | Not Addressed | Not Addressed | While addressed in some agencies as DOE, no agency has the authority to aid the demonstration of innovations in areas except energy and defense. |
| Venture Funds — Private Sector — | Not Addressed | Not Addressed | President Carter acknowledged this problem and indicated that the basic question of innovation profitability will be addressed in a later submission. Without making the innovation process financially rewarding, all other actions are simply window dressing. |

## Exhibit II

# Government Actions in the Development and Commercialization of Industrial Energy Productivity Technologies

| Commercialization Barriers | Product Development Process | | | | | |
|---|---|---|---|---|---|---|
| | Basic Research | Applied Research & Generic Technologies | Pilot Demonstrations | Commercial Sale Demonstrations | Introductory Offerings | Product Maturity |
| Concept Development | Unique Government Role | Principal Government Role | Government Role | | | |
| Matching Market Needs | | Cooperative Programs With Low Industry Funding | Cooperative Programs With Moderate Industry Funding | Cooperative Programs With Moderate-to-High Industry Funding | | |
| | | Energy Studies Rebates for Prospective Buyers | | | | |
| Reduce Manufacturer's Risk/Investment | | Cooperative Programs More Flexible Patent Policies | | | Loan Guarantees | |
| Reduce Buyer's Risk | | | | Direct Subsidies Energy Savings Rebate Cooperative Programs | | |
| Enhance Buyer's Economics | | | | | Investment Tax Credits Depreciation Periods Energy Savings Rebates Tax Policies | |

## Attachment A—Industrial Innovation

### Report of Ad Hoc Committee on Direct Federal Support of Research and Development to Enhance Innovation in the Process Industries

*Introduction*

The Subcommittee on Direct Federal Support in Research & Development of the Advisory Committee in Industrial Innovation draft report (dated December, 1978) defines some valid needs. One need, in particular, is that of coupling universities and industries more tightly so that all industry (specifically small business) could have easier access to the innovative research that can be perforned in the university environment and, at the same time, could provide guidance in the field of research. Although there is no specific disagreement with the needs identified in the subcommittee's report, there is a strong feeling among many in industry that the report is applicable primarily to the mass-produced "product" portion of industry. The report does not appear to consider the unique needs and requirements of what may legitimately be termed the "process" portion of industry.

Based on this perception, a group of more than twenty process-oriented industry representatives formed an ad hoc committee to: (a) Review the draft report; (b) understand the general nature of the views expressed by the subcommittee membership; and (c) determine if additional recommendations or suggested modifications to the draft report would be appropriate.

A list of those attending the ad hoc committee meeting is attached.

*Problems and concerns*

There has been a significant decrease in innovations within the U.S. While there are many theories for this decline, the most important reasons in the process industries appear to be associated with the high cost, high risk and uncertain payoffs due to a lack of demonstration and understanding of the new (innovative) processes. When the technical and economic risks of an innovative process are well defined, the availability and cost of capital become the major problems. The historically high interest rates and tightness of the money markets have resulted in a scaricity of investment capital. Much of the available capital is therefore directed to: (a) Meeting regulatory requirements; (b) product expansion; and (c) plant expansion.

This has the overall effect of severely limiting the amount of discretionary capital available for incorporation of new innovative techniques within the process industries.

These factors result in extremely limited availability of industrial discretionary funding and severe comstraints upon its use for Research, Development and Demonstration (RD&D). However, it is this discretionary funding which is necessary for the development and demonstration of the new innovative processes and new energy supply and conservation techniques. Each discretionary investment must be subjected to a very rigorous risk analysis. The more risky the project, the lower the incentive for any significant investment. Often it is just the perceived risk that discourages the investment, particularly if the investment must span several years.

Basic research and advances in generic technology are very important to industry in general. However, the rewards for this type of research are quite often insufficient to encourage funding by the process industries. In fact, it is not clear exactly how generic technology research will impact upon the acceptance of innovations within the process industries.

Due to the nature of operations within the process industries, an innovative process or equipment must be demonstrated in actual operation. Many process companies have procurement rules that require using a piece of equipment in similar service for one or two years before it can be purchased. The problem is how to develop the experience in similar service. Without a demonstration any innovation cannot have a history of successful operation with a demonstrated reliability and availability record. This is essential whether the equipment is product output-oriented or whether it is being considered as an energy conservation improvement.

It should be noted that many of the largest energy-consuming industries are process industries. Consequently, the process industries represent some of the most effective energy-saving opportunities for Federal R&D efforts.

Although research, in general, is critically important as a source of innovative ideas, research can only be considered the tip of the iceberg. The ad hoc committee did not feel there is a shortage of good ideas (inventions) concerning new techniques which could be used to enhance the process industries. However, there is a stringent requirement for new techniques to be fully demonstrated before commercialization will, in fact, occur. To accelerate the innovation process through implementation

and effective use by industry, requires appropriate Federal support of development and demonstration projects.

*Recommendations*

I. *Development and demonstration.*—The ad hoc committee strongly felt that demonstrations with Federal support in the industrial environment are necessary to enhance the innovation process. The areas of synthetic fuels (inexhaustible sources), new materials, process efficiency improvements and energy conservation are all good examples of the strong need for demonstrations prior to effective commercialization.

It was the unanimous opinion of the ad hoc committee that in today's business environment, Federal funds are needed to support these high-risk demonstrations. The guidelines in defining the relative funding participation by the government and industry need to be flexible so that the risk involved, the societal benefits, and the size of the innovating company are properly considered.

II. *Improve industry-government relationships.*—The ad hoc committee unanimously recommended that the overall climate of government-industry relationships be changed so that the innovation process is directly encouraged. The need for industrial innovation must be understood and nurtured by the appropriate government agencies. It is essential that a more cooperative relationship between government and industry by developed instead of the adversary one which now exists in many instances.

In the area of Federal R&D funding, the most frequent recommendations were removal of conflicting requirements, streamlining, simplifying and accelerating the proposal approval process.

III. *Innovation enhancement incentives.*—In addition to the above specific recommendations, the ad hoc committee urged that the following process innovation incentives be thoroughly considered: (a) Very rapid depreciation; (b) Substantial investment tax credits; (c) Exclusive use of patents for a limited time period; (d) Repayment of Federal RD&D investment via royalty arrangements; and (e) Opportunity to convert demonstration grant contracts to loans when the demonstration is successful and commercialization begins.

IV. *Generic technology centers.*—The ad hoc committee expressed considerable reservation regarding the generic technology centers which have been recommended. Such centers may be needed and could possibly serve very useful functions. However, it was difficult for the ad hoc committee to perceive how such centers would directly enhance or improve implementation and demonstration of innovations within the process industries. In the event that such centers are established, it is essential that their function be clearly defined and that any actual demonstrations be conducted in a real industrial environment. In addition, they must be staffed with very highly qualified people and be formed only in association with a strong responsive industrial client (e.g., NACA/NASA—the Aviation Industry).

*Summary*

Although the ad hoc committee is generally supportive of the recommendations made by the Subcommittee on Direct Federal Support of Research and Development, it urges that the above recommendations for direct federal support of demonstrations be added. The ad hoc committee identified these recommendations as the essential link in the innovation process.

## Federal Support of R. & D. Relating to Industrial Innovation

### INDUSTRIAL ATTENDEES

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*Congressional Attendee*

Brady, Thomas, Assistant to Senator Kennedy, U.S. Congress, Washington, DC.

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[From Science, vol. 203, Mar. 2, 1979]

## Science Futures: The Industrial Connection

(By Edward E. David, Jr.*)

There has been a great deal of discussion in recent times about the state of U.S. science and our innovation system. That system has worked reasonably well in the past, but when one looks beyond the surface, it seems almost paradoxical. The lion's share of science is done in the universities and is lodged in industry. How is it that they get together? Traditionally, there has been a diversity of mechanisms for the transfer of knowledge and ideas to industry and the communication of realistic problems to academic researchers. Some of these mechanisms involve students hired into industry, visiting professorships filled by industrial research people, academic consultants in industry, special courses of study for "retreading" industrial people, professional society publications and scientific meetings, and joint work on government panels.

However, such mechanisms may not be adequate for the future. The fundamental situations of both industry and academia are changing. Industry is being increasingly pressed by competition from abroad as well as at home. New science-based technology is required by industry in increasing amounts, not only to meet this competition, but also to satisfy environmental, safety, and efficacy demands economically. The universities and colleges find themselves in an uncomfortable squeeze by their major research sponsor, the federal government. There is less effective funding on one hand and increasingly onerous regulation on the other. The situation will be aggravated by the falling numbers of students expected in the years just ahead. Academia's greatest need is for long-term support from outside government that will pay the true cost of research. Many administrators and professors view that as highly preferable to arm-wrestling government auditors to stay financially solvent. The time has come for a closer and more intimate relation between industry and academia, but a relation that still recognizes their distinct roles in society.

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*The author is president of the Exxon Research and Engineering Company, Florham Park, N.J. This article is the text of the presidential lecture at the AAAS annual meeting on 6 January 1979 in Houston, Texas.

This article sketches this situation in greater detail, as I discuss the essential features of the U.S. research and development (R & D) system, looking at characteristics of industrial research and of academic research as they might affect any partnership and pointing to the beginnings of this desirable industrial connection.

## ESSENTIAL FEATURES OF THE U.S. RESEARCH AND DEVELOPMENT SYSTEM

The R & D system in the United States is complex and almost defies a neat description. Yet it does show essential features. None is more important than pluralism. Pluralism is provided by the many existing independent institutions. Each has its own role in society. Each secures its own funding and performs research aimed at its own and its sponsor's objectives. Pluralism of funding sources is particularly important given the troubling trend in academic-government relations.

Another element of pluralism is decentralization. That is a widespread theme of management today as corporations and institutions grow. Centralized policy decisions based on macro concepts of the issues have been found wanting when applied to the many diverse situations that arise. A great deal of local autonomy is required for successful and efficient operations. Needless to say, this way of operating is particularly applicable to research and development.

At Exxon, decentralization is a way of life. Our development activities are dispersed over the operating units of the corporation. However, research and engineering are largely performed centrally. The yearly budget is an aggregation of individual budgets modified and approved by central management review. Thus, management proceeds from the bottom up, not the top down.

The second distinguishing feature of the R & D system is its adversarial-competitive nature. In many cases, it is against the law for industrial research groups to coordinate their programs. The scene is typified by numerous groups working independently and competitively. For example, there are at least three major coal liquefaction projects in the United States at present. There are several others in the earlier stages. Multiple solutions or products tend to emerge from such competitive efforts, and these then vie for public favor. Corporations that excel in this competitive process become self-sustaining through reinvestment of funds in new or improved products or processes. But competition and adversarial relations are not restricted to industry. Laboratories in universities and colleges as well as some government laboratories' compete for professional recognition, prizes, and future funding.

The third feature of the R & D system is its dependence on people. Personal excellence and leadership in R & D are highly valued. The rewards can be great in both satisfaction and more tangible terms. The competitive atmosphere means that the most effective people tend to rise to positions of responsibility and scientific leadership. Maintaining a cohort of achievers is a necessity for a healthy system. This is a major objective for academia, and both government and industry have traditionally aided academic institutions for this purpose.

Depsite the importance of these three factors to the health of research, there are tendencies on the national level to deemphasize pluralism, competitiveness based on technical excellence, and dependence on high achievers. This trend is politically driven. Coupled with industry's need for new technology based on science, it implies a driving force for a new synergistic relationship between the scientific community and industry—the industrial connection. Before discussing this matter, let me go further into the state of industrial innovation and the nature of industrial research today.

## INDUSTRIAL INNOVATION TODAY

The most recent projections of 1979 expenditures by industry on R & D approach $25 billion, continuing a rise in activity over the past 5 to 10 years, except for recession times. This amount is now about equal to federal expenditures. The majority of the nation's scientists and engineer's are employed by industry, most of those in pursuits which are aimed at the civil sector.

Beyond such figures, however, there are major transitions in progress. Foreign competition has burgeoned both in domestic markets and where U.S. industry operates abroad. Federal regulations have made it much more difficult and expensive for industry to operate. Foreign governments have thrown up a plethora of protective screens which restrict access to their markets. Economic nationalism is on the increase.

For industry, the bottom line from these pressures is the growth of uncertainty and the corresponding increase in risk for investment in new business and facilities. The industrial management culture can handle almost any well-defined situation. It

is bewildered by uncertainty, particularly that generated outside of the market mechanism. Socially generated political pressures are particularly fearsome. Yet, depite these difficulties. I find no industry throwing in the towel. Most are making major efforts to surmount the difficulties and to continue to prosper. It is true that these pressures have focused management's attention on the short term, resulting in a similar concentration for research.

Beyond this well-documented effect, the market for research is down. By that I mean that there is a decreasing demand for certain of the results of research. This decreased demand occurs in cases where regulation, license requirements, and controls have increased the cost and time for commercialization of products and services that could arise from new knowledge. For example, chemistry is such a field. Marketing a new pharmaceutical or fuel additive is much more costly and time consuming than it was only a few years ago. Regulatory uncertainties also contribute to a decreased demand for research in fields such as medical technology. Some other fields have been less affected; for example, new computer-based products for the calculator, amusement, and business markets. These are still able to make rapid use of new possibilities from research. Overall, however, uncertainty and regulation have been blamed for a major decrease in the demand for innovation. The case cannot be proved except in some specific instances, but in my opinion it is real and substantial. There is no reason to believe that this regulatory situation will recede, despite its negative influence on economic growth, and despite the spoken intentions of top government officials to invigorate innovation.

Actually, the situation with industrial R & D is healthier than is indicated by this outlook and much of the current rhetoric. There is a remarkable degree of vigor in evidence at industrial laboratories. Indeed, because of or in spite of increasing regulation and competition, many industries are becoming more technologically sophisticated and require increased science-based research. Many people believe, and I am one of them, that much of the best research today is going on in industry.

I have already noted the troubles that appear in the commercialization phase of innovation. The high cost of money, long lead times enforced by delays in obtaining permits, and uncertainties about liability and the market make commercialization more difficult than ever. However, these barriers have not affected the quality and number of ideas for research. Those with the greatest push will progress through the innovation chain and change the world as in the past. This innovation will be facilitated by high quality research in modeling, public policy, environment, markets, and societal effects. It is this vigorous outlook that gives hope regardless of the obvious impediments to traditional paths of innovation. Industrial innovation will not atrophy.

## NATURE OF INDUSTRIAL RESEARCH

Much of today's discussion about industrial research and innovation has centered around the topics of barriers and incentives to innovation. I have already said that the barriers are not likely to recede, and I doubt that new incentives will offset them. Yet, with suitable adjustments, technological innovation can proceed. A reduction of uncertainty could help, as could fewer, clearer regulations, rules, and standards. There are other matters peculiar to industrial research worth mentioning as they relate to "the industrial connection." A discussion of them will lead us to a number of ways for academic and industrial activities to augment each other.

Let us begin with basic research. There have been endless arguments over the years about definitions of basic research, and I will not repeat them here. However, it is true that industry tends to view basic research very differently than do government or academia. The National Science Foundation (NSF) definition relies upon motivation for the work as the distinguishing feature. According to that definition, the motivation for basic reseach must be the extension of knowledge and not application. This definition is not appropriate for industry. First, the motivation of the industry and that of the researcher may be different, and often is. More importantly, the NSF definition ignores the character of the work itself and its results. Industry would say that any work which produces new understanding is basic research, regardless of the motivation. I could go on with this argument, but I think the point is clear: industry's view of basic research is output-oriented just as is its view of R & D generally.

Let me give two examples. As an industrial researcher, I have no hesitation in saying that the emergence of Information Theory from the Bell Telephone Laboratories was the result of basic research, even though Claude Shannon clearly had in mind its application to the improved design and performance of electronic communication systems. According to the industrial definition, my company, Exxon, has basic research not only in our Corporate Research Laboratory in Linden, New

Jersey, but also at our synthetic fuels lab in Baytown, Texas, and in our catalyst activities in Baton Rouge, Louisiana. According to the NSF definition, only a fraction of our Corporate Laboratory work would qualify.

Now this point is not merely a definitional matter. It is the essence of the philosophy behind industrial research. Research in industry is concentrated in fields of obvious importance to the corporation's function in society, and its ultimate aim is to better the performance of that function. Such research should qualify as basic if it is done in the best scientific tradition with the results subjected to peer review, and if it contributes to the knowledge base. More and more corporations are taking this view of research.

That in turn means that basic industrial research is probably larger than current figures would indicate but, more importantly, it is expanding. But the philosophy behind it is a far cry from that of the 1950's and early 1960's. That was the era when many corporations established research laboratories only loosely linked to their function in society. This was an act of faith that unstructured research would produce great results and a sterling image. Disillusionment set in in the late 1960's and many of those laboratories have disappeared. The current emergence of research activities is more measured, but is also much sounder in my view.

Modern industrial research tends to be organized along interdisciplinary lines. Industry is not likely to have chemistry, physics, social sciences, or electrical engineering departments specifically. Neither, however, is there a pure project orientation. Work tends to be organized around macro disciplines or functional lines. At IBM, for example, some of its research is organized around the functional units of computers: logic, memory, organization of data, and software. At Exxon, our research is organized around such subjects as surface science, separation of chemical or physical species, laser chemistry, catalysis, and materials. Our organizational units tend to be strongly interdisciplinary therefore. The subjects are chosen for their importance but also because they are fields where new ideas promise progress.

More than this, industrial research is expanding its scope profoundly. Companies and corporations at one time viewed their interests narrowly—restricting their concerns in research to that clearly involved in the technology of their product lines. Today, a broader point of view dominates the scene. For example, many corporations are interested in policy research, economic models, and the sociology of the cohort from which they draw their customers. Furthermore, they are sponsoring research in these subjects. At least limited interest in the social sciences is also being evidenced. One source of this interest is the very large sums spent by industry on education and training, said to be larger than the total of academic budgets.

Studies of educational methods and techniques are being carried out in many corporate laboratories. Both continuing and remedial education are included, as are both knowledge and skills. There are a number of behavioral laboratories in industry, and a good deal of research on subjects in experimental psychology; for example, in visual and auditory perception and in motor skills. All of this means that industrial research is becoming much more diverse, and is not focused entirely or even principally on hardware or products. Furthermore, the systems approach to design and business planning for innovation is coming to dominate the scene.

I have not even mentioned the environmental, safety, and efficacy fields which themselves are generating major research efforts in industry, as is the effort to make products more reliable, more repairable, and "fail safe" or "fail soft." The research on failure modes of systems is becoming a discipline in itself.

Another aspect of the industrial scene is the increasing cost of development. A case in point is the developmental pilot plant and accompanying experiments for coal liquefaction at Exxon's Baytown, Texas, installation. That program will cost one-quarter of a billion dollars. The era of "big science" is being joined by the era of "big technology." This trend is placing a premium on techniques for containing developmental costs. Thus, research is being carried out on the development process itself.

Another characteristic of industrial research is its insecurity. I do not mean that it fears capricious elimination or even erosion during economic downturns. (Research directors have learned how to manage such swings within limits.) Rather the insecurity focuses on the quality of the research. Industrial managers feel comfortable with development. There the performance goals can be clearly stated, the project can be priced, schedules laid out, milestones established, and so on. The quality of the effort can be assessed against those yardsticks. Managers feel much less comfortable judging the scientific quality of research results. Yet, industrial scientific research requires a high level of stewardship because of its isolation. Individual laboratories are isolated by the competitive nature of industry enforced by the antitrust laws. Cooperative research and exchange of results between indus-

trial research labs is forbidden by law in many cases. Competition also delays publication in some instances. Thus, industrial research can stray far off track before that becomes apparent. Since research in industry, as elsewhere, has a long lead time to commercialization, the usual evaluation tools based upon commerical output do not apply. Thus, evaluation is one of the principal puzzles of industrial research.

This sampling of activities and trends hopefully gives the flavor of industrial research today. It increasingly makes use of the basic research paradigm in forwarding the industrial function. The scope of industrial research is growing apace; not only are policy, social sciences, and behavioral sciences becoming legitimate subject matter, but also interdisciplinary groups are the preferred mode of organization much more broadly today. Systems-thinking is becoming a dominant feature. The cost pressures of "big technology" are leading to research on the R & D process itself. Finally, industrial research has substantial difficulty in evaluating its ongoing activities. This developing picture reveals one side of the industrial connection. Perhaps you will agree with me from the sketch of industrial research that an academic element would be beneficial to industry and would not necessarily be incompatible with first-rate academic research.

## THE ACADEMIC SIDE

Now turning to academia, there is no doubt that there are increasing administrative burdens on research performers. Professor Wiesner's recent speech on the subject has been widely publicized. Dr. Charles Overberger of the University of Michigan has also spoken to this subject when receiving the ACS's Parsons Award. Both of these distinguished academicians pointed to federal regulations as being a major factor toward increasing the administrative and accounting load on research institutions, as well as constraints and pressures to point their work toward the latest national need or congressional interest. Both Wiesner and Overberger believe that the 30-year relation between the government and the universities is breaking down, or at least changing radically. This trend has yet to run its course.

This is not the only trend affecting research and science today. There is the increasing average age of the tenured faculty in research universities, and the changing employment patterns of young doctoral graduates. One can suggest other trends which promise to affect academic research. The effects are not evident from gross funding statistics. Nor can they be offset by increases in gross funding of research, no matter how much we like to hear of yearly growth in the federal research budget. The effects go to the root of research priorities and style. Traditionally, priorities have been set by the notion of a shortening time scale in response to increased demand for bringing results from the laboratory to impact on society. Style has been set by the idea that research excellence earns increasing autonomy in day-to-day work. Federal policies imply that these ideas no longer reflect the situation.

Just how the universities, and research and science generally, will adapt to these changes is not clear. It is clear that the prominent features of the R & D system listed earlier are worth preserving to keep the system effective. I believe that the industrial connection can aid in preserving these features.

## STRANDS FOR THE INDUSTRIAL CONNECTION

Academia and industry have had a long and fruitful relationship. The colleges and universities have been the suppliers of scientists and engineers. Industry has been more or less generous in its support of academia. However, when the federal government increased its support to record levels in the 1950's and 1960's, industry did not try to compete. Many of its fellowship and scholarship programs were dropped in favor of NSF. NASA, and NIH. Industry had never supported substantial amounts of research in academic institutions. However, there were some continued contributions for specific purposes. Industrial associates programs emerged at the universities in the 1960's and provided some small income for the universities and a link to industry. But most of this sort of activity might be described as philanthropic and does not result in a working connection. I hasten to add, however, that contributions of relatively modest unrestricted funds to the universities can produce benefits far out of proportion to their amounts.

Well beyond this mode of philanthropic interaction is joint research. Of course, there has been much lip service to such joint projects in the past. But major efforts have foundered because of the conflicting roles seen by the potential participants. Issues hinging on patent ownership and licensing, publication rights, protection of proprietary data, and so on have proved difficult to resolve. However, in recent

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times there has been progress, perhaps due to the pressures on industry for innovation and on academia for long-term, unconstrained support.

Harvard University and Monsanto have negotiated an agreement in which the knotty issues have been largely resolved. The agreement provides support for certain selected faculty members and some of their students on a long-term basis, say 5 to 10 years. There are provisions for Monsanto scientists to become involved and to work jointly on ideas and research topics. Rights to inventions are arranged so that Harvard retains ownership of its own contributions, but provides exclusive license to Monsanto for a specific period providing the inventions are progressing toward commercialization. The agreement itself is a complex document but it is remarkably cooperative in tone. Other companies including Exxon are exploring such long-term cooperative arrangements.

Academic advisors for industry have a long history too. Most often the arrangement is through a consulting contract. However, a broader instrument, the outside advisory committee, composed of distinguished scientists, is becoming widely used. For example, IBM, General Motors, and Gould, among several others, have such committees. Some advisory committee members are also on the corporate board of directors. Such committees evaluate programs, particularly helping with that vexing evaluation of research to which I referred earlier. They also provide a direct route for voicing research ideas and imperatives to the top management.

Another area of increasing importance for academia-industry interaction is the study of public policy issues. Such studies are increasingly dependent on sophisticated models, economic and otherwise. Studies done by the industry affected by the policy are not credible. Thus the university can play the role of the honest broker. To avoid even the appearance of conflict of interest, policy studies should have at least several sponsors. Industry support of broad-based activities at university policy centers is perhaps best of all.

I could go on but it seems to me that just the above indicates the rich field for cultivation by the universities and industry together. There are mutual benefits to be gained. The pressures pulling the potential partners together, I believe, are inexorable and fundamental to the evolving situation. I do not expect to see an immediate embrace, but 10 years from now I do expect to see a vigorous community of industrial-academic scientists with its academic members enriching industrial research and industrial organizations providing the link to commercialization.

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## Science and Industry, Challenges of Antagonistic Interdependence

(By Peter F. Drucker*)

Science and industry in the United States used to enjoy a relationship of mutual respect based on an unspoken conviction that they depended on one another. That relationship, while distant, was uniquely productive for both science and industry.[1]

The first change in the traditional American relationship occurred after World War II. Research became fashionable in industry and government alike. These were the years when the stock market valued a company according to the amount of money it spent on research, and in which a lavish campuslike research center was considered proof of a management's competence. Similarly in those years—culminating in the space program of the 1960's—science and research increasingly came to be seen as the mark of the effective well-planned and properly progressive government program.

During the years after the war, the ability of America to convert science into industrial application was considered the outstanding strength of both American science and American industry. Treatise after treatise pointed out that the British, for instance, were America's equals in science. But the British failed to convert their own scientific achievements—in electronics, in polymer chemistry, in the computer, in radar, or in aviation—into technology, products, and economic advancement, whereas America did.

Equally, especially during the Truman and the Kennedy years, the willingness, indeed eagerness, of the American politician and government executive to apply

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[1] I know of no comparative study of different models of integration of science and society. The few Marxist analysts, such as George Lukacs or Lancelot Hogben, wore nationalistic blinkers; Lukacs, for instance, assumed the German model to be universal.

science—"hard" as well as "soft"—to both the study of social and political problems and to the design of social and political programs was seen both inside this country and outside as a distinct and great American achievement. The innovating ability of American society was widely explained throughout the world, including the Communist countries, as the result of the sensitivity of the American scientist to political and social needs and opportunities, and to the values and dynamics of the political process.

In quantitative terms, the relationship seems to be as close as ever—and perhaps even closer in computer sciences, solid-state and nuclear physics, the earth sciences, and biochemistry. It might be argued that nothing has really changed despite all the talk of irrelevance of science or of the talk of the wickedness of "American Imperialism" by the vocal critics on the New Left, despite Vietnam, despite inflation, and so on. One might indeed assert that the highly publicized and highly visible developments and media events—the headline- and demonstration-makers—are little more than white-caps on the surface of the ocean.

Yet there has been a major change, not in the measurable realities of the relationship between science and the decision-makers in industry and government, but in the moods, the values, and the meaning of the relationship. There is today distrust, disenchantment, mutual dislike even, and, worse, lack of interest in each other on both sides. American scientists today, in large number, tend to suspect the traditional relationship as being tainted or impure. Industry still professes to honor the relationship and to respect research. But industry's actions no longer fully live up to industry's professions. As to government, there is now a strong tendency to judge science by what is politically expedient or politically fashionable; that is, to attempt to subordinate science, whether pure or applied, to value-judgments that are the reverse of, and largely incompatible with, any criteria one could possibly call scientific.

In both industry and government, there is even increasing doubt whether science and research do indeed lead to results. It is often argued that this reflects lengthening lead times resulting from the increasing complexity and specialization of today's advanced scientific research. But there is no evidence that the lead times have lengthened; the time span between new theoretical knowledge and the first application is the same 30 to 40 years that it has been all along (for example, between Maxwell's theory and Westinghouse, between x-ray diffraction and Carruthers' development of nylon and polymerization, or between quantum mechanics and semiconductors). What is changing are not facts but faith. On both sides the mood is becoming one of alienation and perhaps even of recrimination. It is a dangerous mood, above all for American science and American scientists. Both sides stand to lose, but science stands to lose far more.

### WAYS OF INDUSTRY

The mind-set and values of industry—but equally of the government decision-maker concerned with effective policy—are in danger of becoming hostile to the needs, the values, the goals, and the perception of science. One reason for this is the increasing pressure, especially in an inflationary period, to produce results fast. An inflationary period, by definition, is one that erodes and destroys both industrial and political capital. In an inflationary period the existing value of future results is subject to the exceedingly high discount rate of inflation which, in effect, means that no results more than a year or two ahead have any present value whatever, whether value is defined in economic or in political terms. It is, therefore, not a period in which either industry or the policy-maker can take risks.

Thus both industry and the governmental policy-maker in an inflationary period concentrate on small, but sure and immediate, payoffs; that is, on what can be calculated with high probability. The application of true scientific knowledge is by definition a big gamble in which payoffs are far in the future and thus exceedingly uncertain although very great in the event of success. In an inflationary period, the industrialist or the policy-maker is almost forced into the small but quick payoff of a lot of small and, by themselves, unimportant projects that require very little science altogether and can only be damaged if exposed to too much science.

### TAX EFFECTS AND INVESTMENTS

More important perhaps—or at least more insidiously deleterious over a longer period of time—is taxation. The tax system adopted by the United States in the last 20 years or so penalizes basic research and the adaptation of basic research to technology. Worse, through the combined working of corporation income tax and

capital gains tax, the system greatly favors short-term, immediate gains and makes long-term investments in an uncertain future unattractive and unrewarding.

Equally inimical to investment in research and innovation is the increasing burden of regulation. It is not primarily that regulation adds cost, but that it creates uncertainty. Whether in respect to the environment, to safety, or to new drugs, regulation makes investment in research irrational, not only increasing the odds against research producing usable results but also making research into a crooked game.

Tax laws and regulations also push industry away from technology focus and toward financial conglomeration. Under the tax laws of the United States—laws which in this form do not exist in many countries—the proceeds of liquidating yesterday are considered profit and are taxed as such both to the company and to the investor. Hence, businesses, instead of liquidating the obsolete, have to find new investments in new businesses for whatever cash is being released in the shrinkage of an old technology, an old product line, or an old market. And this, in effect, imposes conglomeration on them. This policy makes it increasingly difficult to shift resources from low and diminishing areas of productivity to areas of high and increasing productivity and this impedes innnovation. It also shifts businesses from a technological to a financial focus. It makes management increasingly a matter of finding the right financial investment.

### THE ANTITRUST BIAS

This constant pressure of the tax laws, which results in a swerve from the scientific and technological toward the financial and from the long term toward the short term, is then aggravated by the antitrust laws, which probably are responsible more than any single factor for turning American industry away from building on a technological, science-oriented base and toward the financially based conglomerate.

In the world economy, even businesses that are very large on the national scene are becoming marginal, if not too small. The "big business" of 1938 or even 1958 is a small, if not a marginal, business in the 1979 world economy. Yet our antitrust laws frown on the scaling-up of businesses except through the formation of conglomerates, which, however, lack the fundamental core of technological unity. This conglomerate is focused on financial rather than on technological results. Hence, investment in long-range research and in the application of scientific knowledge to economic production becomes difficult in the conglomerate scope and are good at building and running conglomerates are financially oriented people. Yesterday's business, with its unified technology, organized around a process, such as making glass, was basically technologically oriented and therefore looked to science for its future. The conglomerate, which comprises everything from tin cans and electronics to fast-food restaurants and dress shops, from airlines to banks and toys, is, of necessity, financially oriented. Research becomes a cost center rather than a producer of tomorrow's wealth.

Similar forces operate in government in respect to the interest and the investment in science. Even the most shortsighted businessman still has to focus on both the short term and long term. But a governmental budget is always myopic. It knows no time span other than the fiscal year. It has to justify allocation of resources on the basis of short-term and mostly political expediencies. This was one reason why some older and wiser heads in American science warned against dependence on government 25 years ago. Their fears proved well founded. As soon as science ceases to be an article of the faith and popular, and becomes one application of governmental funds rather than the application of governmental funds, the pressures of the budget process make science a low-priority choice for politician and bureaucrat alike.

There is also disenchantment with the results. Whether science oversold itself or whether industry and government expected miracles, is beside the point; the results that business and government anticipated when they rushed into lavish expenditures on scientific research have rarely been attained. Surely, the relation between scientific work and results, whether in terms of goods, services, or such benefits as better schools or better health care, is far more difficult and complex than either scientist or policy-maker thought.

As a result of these pressures and developments, industry and government are drifting toward what might be called a scholasticism of the budget in which the budget is a closed system, with its own absolute logic.

Both the business executive and the governmental executive proclaim their faith in research, but neither can practice it today. The mind-set of executives, whether in business or in government, and their values thus inexorably shift from what Thorstein Veblen about 60 years ago, called "the instinct of the workmanship to

what he called the spirit of business"—the right term today would be "the spirit of the budget." It is a shift from a concern with the creation of wealth-producing resources toward immediate payoffs. It is a shift in cost-effectiveness from emphasis on "effectiveness" to emphasis on cost. And this trend is perhaps a good deal more pronounced in government today than it is in business.

ESTRANGEMENT

Let us now look at what has happened to change the mood, the mind-set, the values of American science. Those changes, or at least their underlying causes, go back to an earlier period during which the relation between science and its non-scientific patrons and customers both in industry and in government seemed to be closest, most harmonious, and most productive.

American science first began to feel uncomfortable in the traditional relationship of mutually advantageous coexistence. Or perhaps science was uncomfortable all along, but did not see any alternative until after World War II, when government emerged as its rich and more generous patron. Whereas industry had at best spent hundreds of thousands and hired a dozen scientists, the government spent billions and seemed to have an insatiable appetite for well-paid science professionals in an ever increasing number of government agencies.

Even more appealing: Government increasingly offered scientists, including a great many junior ones still at the beginning of their scientific careers, the best of both worlds—to live in academia on a Washington income. No wonder that grantsmanship rapidly became the most prized and the most accomplished of the liberal arts. And where industry, whenever if offered support, had the insulting habit of expecting results, government, or so is seemed, was willing to support the scientist for science's sake. Indeed anyone who in the palmy days of the early 1960's raised such nasty questions at the accountability of grants-receiving scientists for performance and results, risked being branded an anti-intellectual. And anyone who then doubted that government support would continue to grow, let alone whether government's intentions were truly honorable, was likely to be dismissed as an old fogy.

As a consequence, science became accustomed to large sums of public money, in return for which it then had to accept political rather than economic yardsticks for success and performance, the main yardstick being whether a program for the support of this or that major scientific enterprise could be sold to the governmental policy-makers; and—a logical consequence—whether this or that search for knowledge fitted the political ideologies and popular fads of this or that clique or faction. Thus American science, quite understandably, came to consider the question of economic application and economic benefits to be irrelevant and irksome, if not somewhat demeaning. Few raised the question whether political favor and acclaim might not be equally irrelevant and perhaps even more demeaning as yardsticks of scientific achievement.

But I would consider even more crucial in the estrangement from industry on the part of science the fact that, for the last quarter-century, work in graduate school has come to focus on the production of Ph.D.'s, certified for teaching in institutions of higher learning. Prior to World War II, science teaching in the university focused on undergraduates, on students who were unlikely to make science their career. In graduate school the focus was largely on the preparation of research scientists for outside laboratories, that is, in industry and, to a lesser extent, in government. The best graduates were the ones who then got the good jobs in industry; other jobs for graduate scientists were exceedingly scarce.

The "educational explosion" of the mid-1950's, of necessity, meant a shift in focus to basic theory, which is what an undergraduate teacher teaches. It meant, of necessity, a loss of close contact with industry. For one's brightest graduates no longer went into industry—and it is largley through his graduates that the university scientist stays in contact with the world outside of science. Indeed the distinguished scientist's best students did not even go into undergraduate teaching, but stayed on in graduate teaching and graduate research. The educational explosion made the scholar into an industrialist who produced graduates. Graduate school became a growth industry, and the univeristy largely became a closed system, preparing people for its own continuation and perpetuation.

This also changed the meaning of research. Research now became something for which one gets entitlement to a specific type of job, to promotion, or to tenure. It became a ticket of admission. Whenever a piece of work becomes a ticket of admission, it becomes increasingly formalized. It increasingly focuses on satisfying requirements rather than on producing results.

Again, 15 years ago only an "old fogy" would have dared to suggest that graduate school enrollment and, especially, enrollment in graduate programs preparing for

teaching in graduate school would not and could not expand indefinitely. Long after the "baby bust" of 1960–1961 had occurred—indeed long after it had clearly become irreversible—graduate schools, and especially those in science, continued to intensify their efforts to produce larger numbers of graduates trained and mentally prepared for rapid careers in the academic "growth industry," of the ever expanding university. When the university stopped expanding, these graduates then understandably felt let down. They did not blame the university which had led them on and had overpromised. They did not accept the facts of baby boom and baby bust. They tended to blame the outside world, namely, industry and government.

These developments may account for what, to the outside viewer, seems to be the most fundamental shift of all. This is the shift toward a definition of knowledge as "whatever has no utility and is unlikely to be applied." This is not a form of Marxism, let alone social responsibility. It is incompatible with any philosophy of society or economy. And it is far more elitist, and in the worst possible way, then the so-called elitism of the traditional scholar. It is a view of science as existing primarily for the sake of academia.

The American scientist, by and large, still involves Francis Bacon as his patron saint. But to an outside observer, and especially an outside observer located in the employing institutions other than the university itself—that is, in government or industry—it sometimes seems that American science is rapidly shifting to its own neo-scholasticism, its own closed system. Like any scholasticism, it suspects experience, despite its emphasis on experiments. It tends to reject utility, application, technology, and any kind of payoff altogether. To the outside observer it looks as if the mind-set and the values of American science are becoming incompatible with, or at least alien to, application, utility, and results.

## THE DANGERS

The drift of science and industry from mutual respect and advantageous interdependence to the antagonism and alienation which characterize the last 10 or 15 years, is dangerous first to American industry. The great danger is that what I have called the "spirit of the budget" will paralyze the ability to innovate and to change.

We know very little about the actual relation between scientific knowledge and technology, but we do know that science creates both vision and performance-capacity. It would be a very poor trade-off to exchange the increased analytical capacity of the policy-maker in government and business for lack of vision, lack of will to innovate, and paralysis of the capacity to change. We face a period in which ability to change will be crucial—with the impacts of 20th-century science on our vision, as well as on our technology and our way of life, just beginning to be significant.

The danger of the drift into antagonism and alienation is, however, even greater for science than it is for industry. It is possible, and even fairly easy, to buy the application of science. By its very nature, science is public. Technology, the application of science, is usually available in prepackaged and applicable form and for a reasonable fee. This has been proved by such totally different countries as the Soviet Union and Japan. In both, investment in science has been kept low—in the Soviet Union it has essentially been focused on a few selected areas considered of prime importance for defense; and in Japan it has been reserved for areas that were considered intellectually prestigious. In both countries, the technological fruits of science were readily available by purchase from the outside world.

It is not true, in other words, that a modern developed country needs a science base. It can purchase it or import it. If American science loses the support of industry and of government policymaker because it spurns both in the name of scientific "purity," it may find that for long years to come the country can get along without it. Ultimately there may be a very high price to pay—but this may well be far into the future.

In purely opportunistic terms, American science can therefore ill afford to be estranged from industry. Clearly the expectation that government would turn out to be a more reliable, let alone a less demanding, patron than industry can no longer be maintained. Government may turn out to be a far less dependable and a far more restrictive patron than the economic sector would ever be. Certainly, government is likely to impose political values on science, far more than pluralistic and atomized industry would ever do, whether this is in respect to biomedical research with its politically popular fads and crash programs, in respect to the demand that scientific research be focused on projects rather than on knowledge, or in the demand that what is science is what elects politicians or what pleases an intellectual mob.

Equally, it is no longer able to anchor American science in the graduate training of Ph.D.'s for college or university teaching. Colleges and universities will for long years to come be amply staffed, especially in traditional scientific disciplines. At the same time, government employment for scientifically trained people has reached a plateau, and may indeed go down rather than up—both because the pipelines are full and because spending cuts are likely to fall on areas of long-term promise—that is, on areas that employ scientists in large numbers—rather than on areas of immediate performance.

For the next 25 years or so, American science will therefore have to look to industry to find employment for its graduates. It will again, as it was 40 or 50 years ago, become the rule to expect one's ablest graduates to fine employment and livelihood in industry. The alternative is a sharp curtailment of the academic establishment in science, and especially of graduate work in science, and almost certainly a drop in standards and quality.

### THE PHILOSOPHICAL ISSUE

Modern free society rests on three foundations: autonomous local government as opposed to the centralized bureaucracy of enlightened absolutism; the autonomy of science as independent value and self-directed intellectual inquiry; and pluralism in the economic sphere, in which autonomous self-governing institutions in the pursuit of their own mission promote economic well-being. The three are interdependent.

Of the three, industry has shown itself capable of survival even if free society is snuffed out. In the most totalitarian society, the economic unit—that is the management of industry—is still autonomous. Whenever a modern tyrant tried to subordinate the economic institutions to the all-powerful Party, he failed, and very soon. Stalin's successors learned this lesson and so today do the successors of Mao in China.

Science, by contrast, has proved to be fragile, easily subordinated to tyranny, easily swallowed up in the bureaucratic appartus of a totalitarian system. Science in other words, has a greater stake in the survival of an autonomous and self-governing industry than industry has in the survival of an autonomous and self-governing science.

The deterioration in the science/industry relationship may be only a symptom of far more profound changes in world view way below the surface. But the change is in itself a dangerous, a disturbing, a painful symptom that deserves being treated.

Most needed perhaps is an attitude of responsibility on the part of science. It is no longer permissible for scientists to dismiss the difficult question of the results the laity might expect from scientific endeavor and research. To say, as scientists are wont to do, that scientific knowledge is its own result beyond appraisal or measurement, could be justified when science was a marginal activity. For this is an argument with which one justifies a small luxury, or a harmless self-indulgence. We may never be able to measure scientific results, let alone to plan them. But science may—and should—be able to tell us what to expect, what to anticipate, and how to judge. Science is unlikely to be measurable. But it might hold itself accountable.

Such a change in attitude may not cure anything. But it would enable science, industry, and government to function better and more productively. And the initiative clearly rests with science. We may never be able to work out the complex relationship between science, technology, and innovation—whether in the economy, in education, or in health care. But that the scientist has a stake in the relationship and in its productivity needs to be emphasized—and most by the scientist.

But industry and the decision-makers in government also need to change their attitudes and correct their vision. They know that slighting research and long-term work is dangerous and may even be suicidal. The means to convert this knowledge into action is systematic abandonment of the obsolete, the outworn, the no longer productive. In a few businesses this is understood. There every product, every technology, every process is considered as becoming obsolete, the only question being "how fast?" And then an attempt is made to assess the amount of the new, and especially of the new science and technology that is needed to fill the gap, accepting that of every three major innovative thrusts, one at the most is likely to live up to its promise. For most businesses, however, this is still something only talked about—if not something stoutly resisted as a threat. Most businesses—and practically all governments—seem to believe that yesterday should last forever.

The traditional relation between science and its customers in the economic and governmental system was based on mutual respect and understanding and a keen awarendess of interdependece. American science must effect a return to these values however old-fashioned they now appear to be.

## The Problem of Industry-University Interaction

(By George Bugliarello, President, Polytechnic Institute, New York, Brooklyn, N.Y.)

*Introduction*

Perhaps we should start by asking: Is there a problem with industry/university interaction in our country? Before attempting to answer this question, let us look at some background facts.

In the first place, today university research is overwhelmingly oriented toward federal programs—rather than programs that are industrially oriented.

Secondly, the largest amount of basic research supported by the federal government is carried out by universities, not by industry. Throughout this paper, I shall focus only on research in engineering and the physical sciences. Different considerations, albeit not so different in their final implications as to the role of the university, would apply to research in the biological sciences and medicine.

Third, in the past thirty years most of the research and development activities in this country have been supported by the federal government rather than by industry.

Fourth, the influence of industry on the processes of accreditation and ratings of engineering schools, and on federal allocation of R&D funds for university programs, has been at best very limited.

Fifth, the financing mechanism of public universities does not make it necessary and, at times, even possible for such universities to strongly respond to the needs of industry. There are of course, exceptions, as we shall note.

Finally, whether public or private, our universities have a limited knowledge of industry beyond that gained in activities such as consulting by faculty members of internships of students. An understanding of the overall socio-techno-economic dimensions, thrusts and problems of industrial institutions is usually lacking. Conversely, at times there also appears to be a lack by industry of realistic knowledge of the dimension, thrusts and problems of universities.

The picture that emerges is one in which industry and the universities, in the pursuit of their vital functions, proceed on parallel tracks with only limited interchange and cooperation. The university does not respond as effectively or intelligently as it could to the needs of industry, and industry, in turn, fails to take full advantage of the capabilities of the university.

We must conclude that there is, indeed, insufficient industry-university interaction. This constitutes a problem of lost opportunities that in the long run, as technology becomes ever more sophisticated, can only weaken the technological strength of our country. The remedy must emerge from an analysis of each of the facts just outlined. Let us attempt to look at each of them in greater detail.

*Federal orientation of university research*

Universities do research primarily in response to federal needs. A few years ago we studied the situation in Illinois [1] and found, for instance, that in 1970–71 the largest academic performer of engineering research in the state (the University of Illinois at Urbana-Champaign), had been performing almost $10 million of federally-oriented research but only $354,000 of industry-oriented research. (The proportion of industry-oriented research has now increased, but remains small.) As we all know, the trend toward federal support of university research was greatly accentuated by the launching of Sputnik in 1957 and the subsequent appointment of Dr. Killian as special advisor to President Eisenhower for the purpose of developing a very active federal program in science and technology. This resulted in a strong interaction between universities and the federal establishment, while the interaction with the industrial establishment remained stationary and often declined.

Furthermore, the interaction of faculty with industry occurred—and occurs—very seldom at the policy level, being centered primarily on specific consulting projects, while significant interactions take place with the federal government at the policy level.

The fact that university research is primarily federally oriented represents a considerable bargain for the federal government. The government pays the marginal but not the basic costs of the research enterprise. In a state university, the basic costs are paid primarily by the state, while in a private university they are paid by tuition and other forms of support. Hence the federal government, while paying only the marginal costs, receives the almost undivided attention of the university faculties able to do research. Because of this arrangement, the federal government

[1] Bugliarello, G. and H. A. Simon, "Technology, the University and the Community", Pergamon Press, New York, 1974.

also enjoys a considerable flexibility in creating or eliminating research programs as they suit its needs. Once the government has achieved its objectives in a given area of research, it can move away from that area, without any further responsibility for the support of the university researchers that were engaged in it. This is quite different from what happens in many other countries, such as the U.S.S.R., where most of the research is done in-house by the government—an important factor in our greater research success. A corollary of the overwhelming federal orientation of research in our universities is that the federal government has well established channels for communication with the university. When it decides that it needs some people from universities, it knows precisely how to reach them. It knows the persons. It knows the mechanisms. It knows the channels. Industry, on the other side, must frequently reinvent the wheel when it wants to reach into the universities. It may know how to reach certain universities, or certain departments in certain universities, but not all the departments at all the universities, or all the faculty members engaged in a given discipline or research line.

*Universities as the chief performers of basic research for the Federal Government*

Universities are the institutions that perform the largest amount of basic research supported by the federal government. In the fiscal year 1978, or roughly 3 billion dollars of basic research in the federal budget, universities will perform about half, or $1.4 billion, industry will perform only $200 million, and the federal establishment about $700 million in-house. Even when it comes to federally supported applied research, the role of universities is quite strong, but the universities no longer rank first. Out of $6.5 billion of federally supported applied research, universities perform $1.3 billion, industry somewhat more, 1.6 billions, and the federal government, with its in-house laboratories, centers, and institutes, some 2.5 billions.

Thus the universities are today the national incubators of basic research and they are also substantial performers of applied research. Of course, not all basic or applied research efforts are financed by the government. There is an appreciable amount of basic research and a substantial amount of applied research carried out in industry and financed by industry. And, of course, not all basic research is useful to industry, either now or in the future. But to the extent that technological development draws on basic research, the universities supply an essential ingredient. Furthermore, they do so by usually making their findings public—a situation that tends to create a serious problem when industry intends to keep its research projects confidential. On the other hand, anybody can take advantage of university research. In this context, the example of Japan after World War II is very compelling. Immediately after the war that country had only a very limited basic research capability. Yet it was able to launch a major wave of new technological development, largely by drawing as freely as it could on the generally available literatures and by sending people to study at universities abroad.

*The assumption of the research burden by the Federal Government*

In 1940, the private sector funding of research and development (R&D) was three times as large as that of the federal government. Now, the situation is reversed, the federal government does far more research than the private sector. This factor mitigates against closer interaction between industry and university, and has implications for our national posture in technology. Increasingly, industry has come to regard basic research as a federal responsibility—a dangerous abdication of functions because federally-guided basic research programs are less likely to be responsive to the needs of industry. Furthermore, when industry has felt the need to do basic research, it has tended to do it in-house. It has really not drawn on the resources of the universities, as the federal government has been able to do so successfully. In the domain of applied research, industry has utilized the university to some extent, but these industry-sponsored applied research programs in the universities are still quite small in comparison with federally supported ones.

*Lack of industry involvement in the accreditation and rating of university programs or rating of academic departments*

The limited interest or influence of industry on educational processes and developments, such as professional accreditation or rating of academic departments, is a factor that would appear to be secondary. But instead it does contribute significantly to making the university less responsive to the needs of industry. For instance, the ratings of the qualify of academic departments by the American Council on Education have been *peer* ratings of academe by academics. They have excluded assessment by the employers of the students graduated from the departments, or by the sponsors of the research activities carried out in the department. (This situation would be analogous to an evaluation of a product of a company by other producers,

rather than by the users). Of course, this deficiency affects the evaluation of engineering departments more than the evaluation of departments in the sciences or the liberal arts. If the corporate R&D directors, project managers, and chief engineers were asked to rate engineering and applied science schools and department, in all probability the ratings would show quite a few surprises.

In recent years, however, the engineering schools, under the pressure of accrediting bodies, have progressed toward closer interaction with industrial needs through the fairly widespread establishment of design experiences as an integral part of the curricula. But in too many schools the design courses still continue to be regarded essentially as academic problems, rather than as studies of truly industrial problems. Finally, as we have noted earlier, industry has had limited influence on the allocation of federal funds for basic research. The primary influence, both in science and in engineering, has come from political and from academic pressures.

*University financing and university responsiveness to industry*

A substantial portion of the budget of public universities comes from legislatures, either state or municipal. Thus the financing of public universities is a political process. Intrinsically, it is not a process governed strongly by the needs of industry or responsive to the influence of industry; industry has not organized itself to influence the process in the same way that agriculture and medicine have succeeded in doing.

There are, of course, very significant examples of engineering schools in public universities that have been responsive to the needs of industry and that have made special efforts to interact with industry. The Engineering Experiment Stations in Illinois and Wisconsin are examples. Other examples are the leadership of Georgia Tech in developing rural industries, and the establishment of industrial advisory mechanisms at a number of public universities. Another example yet is the leadership provided by Dean Landis in organizing this conference. But, basically, we cannot overlook the fact that the financing connection between industry and public universities is a tenuous one. It is considerably stronger for private universities, but these universities represent only half the engineering schools in the country.

*Some obstacles in the university and some opportunities*

There are some obstacles intrinsic in the nature of the university that realistically we cannot overlook as we consider what the university can do in responding to the needs of industry. First of all, it is frequently very frustrating for industry to work with the university. The university keeps to its own schedule, and its cycles of academic activity may not coincide with exigencies of a project. When maximum effort in a project is called for, the graduate students that work on it may need to take time off for examinations or the professors may have to teach an extra course. Secondly, as I have mentioned already, the university may not be easily accessible, and industry may not know how to reach a particular sector of the university. Thirdly, because of its own inner dynamics, the university is much better equipped to do basic than applied research. Finally, the ability of the universities to continue to innovate in research and teaching is beginning to become a matter of concern. At this moment, the average age of engineering faculty members is in the mid-forties, and the average age is unlikely to decrease. If the retirement age will be extended, faculties will be locked even more into the present age pattern. The situation is aggravated by the fact that universities have a fairly strong "trade unionism," whether formal or informal. As a result, the full acceptance of professionals from industry frequently becomes difficult. Conversely, it is difficult for industry to remove some of its best men and second them to a university as teachers. Frequently industry is in a better position to contribute people that are not in key positions, but this does not necessarily favor the development of innovation in universities. Thus, we have a real problem on both sides of the fence.

As indicated earlier, confidentiality of research is another obstacle, but it can be overcome. Universities have frequently worked under extremely confidential conditions, for instance, in defense-oriented research. Nevertheless, the university functions better when research results are publishable.

A factor that affects innovation in engineering schools is that the academic standards for evaluating performance of engineering faculties tend to conform to those of science facilities. Thus the essential ingredient is publications, rather than engineering achievements, which are often far more difficult to assess.

Another significant factor is the fact that engineering schools have become strongly analytical. Best of all, they can train analysts. They do significantly worse in training designers and they do very poorly in training inventors and innovators.[2]

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[2] See, e.g., Bugliarello, G. (Editor) "Invention and Education," Polytechnic Press, New York, 1977.

At the graduate level, a major task of the university is to train researchers, but again, these are overwhelmingly analytical researchers rather than researchers à la Edison or à la Marconi. In brief, intuitiveness and unfettered invention are not the *forte* of most university programs—a fact that must be addressed in strengthening the interface with industry.

But there are also some very positive factors in terms of the potential of the interaction between university and industry that we need to recognize. In the first place, the university constitutes a far more complex resource than one capable only of doing teaching and research. For instance, the university is perceived to be a relatively neutral ground; it has very extensive information banks that are generally much bigger than information banks in industry; it has international connections and it is, of course, multi-disciplinary. Each of these points can be quite significant to industry. Let us consider, for example, the last one: the multi-disciplinary nature of the university. The university has a much broader array of disciplines than those that are operating within the walls of any one industry. We know that creative developments which require only a few steps between the very germ of the idea and its full realization can be carried out effectively at the operating level of industry. Ideas that require a few more steps can be carried out quite adequately in the atmosphere of an industrial research laboratory. But even the largest and strongest industrial laboratories are not likely to have strengths in psychology, in the social sciences, in biology, in medicine which are comparable to those of a university. Yet these areas are playing an increasingly important role in innovation, and will become even more significant as we move toward social technology or bioengineering or genetic engineering.

We must recognize, however, that departmentalization also plagues universities, just as it plagues any bureaucracy, public or private, and thus reduces the university's effectiveness as multi-disciplinary institution. The only barriers which are fairly porous in the university—in terms of the disciplines significant to our discussions—are those between engineering on the one hand and mathematics and physics on the other, and perhaps to a lesser extent, the interfaces with chemistry and economics. Let us emphasize that these barriers are only fairly porous. For instance, even now engineering schools are still learning and using the mathematics and the physics of thirty years ago and graduates of engineering schools are not likely to pursue studies in these disciplines after they have completed their degree. The barriers between engineering and biology and with a number of other important disciplines remain quite strong.

*The need for industry-university interaction*

What are some of the benefits from a stronger industry-university interaction, aside from the obvious educational ones?

Basic research is an essential and expanding need of a technological society which demands all the resources of the universities. However, today research in the universities does not necessarily respond to the basic research priorities as defined by industry. As a matter of fact, industry, with the exception, perhaps, of the high technology sector, has very seldom defined its basic research needs with clarity. A definition of such needs, for the earth-moving equipment industry or the machine tool industry or the air conditioning industry, just to give some examples, is simply not available. And because large segments of industry have not defined their basic research needs clearly or visibly, they have not been able to influence the federal allocations for research or to have the university respond. The university could, however, assist industry in the definition of basic research needs. Here a systematic joint effort is called for.

The multidisciplinary nature of the universities is, as we have seen, another reason for a strong R&D interaction between industry and university. Quite simply, there are certain projects that require the skills which are present in the universities but which would be too costly for industry to assemble in house.

The relatively neutral ground of the university also can offer a significant benefit to industry. Pharmaceutical firms learned at an early stage to capitalize on this perception of the university. The acceptance of new products and new ideas of industry will depend increasingly on factual analysis of performance and impacts. Research done at universities tends to have credibility both with government agencies and the public.

A stronger R&D interaction between industry and university can be important in satisfying the unfilled research needs of many small and medium corporations which cannot afford a strong in-house research capability. But for this to happen suitable mechanisms need first to be derived. I believe that it is in the national interest, as well as in the interest of industry, that we do so.

The full utilization of the university as a resource for industry will, of course, also be beneficial to the university itself. It will diversify and stabilize its sources of support, which today in a private university depend overwhelmingly on enrollments and federal research, and in a public university are dominated by the contributions from state or local governments.

We may derive comfort from the fact that the problem of the relation between the university and industry is not limited to the United States, but exists almost everywhere in the world. Actually, in this country we have been doing better than other countries: Communications between the university and industry have been more effective; boards of trustees of private universities have strong representation by industry; conferences, such as the present one, occur periodically, and there is considerable movement of personnel from industry to the university and vice versa. In the U.S.S.R. on the other hand, the university is very tightly compartmentalized. It excels in science, but it is very poor in responding to the research needs of industry. Things are better in some other countries of eastern Europe. For instance, in Romania the connections between industry and university are quite strong, and the university does a considerable amount of research of direct industrial significance. As a result of these efforts, one begins again to see, for instance, the emergence in eastern Europe of a very strong machine tool industry that inevitably will be a serious competitor for our own industry. In western Europe, considerable communication between the university and industry exists only in certain sectors. Historically, we know that the great development in the chemical industry in Germany stemmed from the creation of graduate universities. In a number of other sectors, however, the interaction today is weak. In effect, western European industry is not as able to take advantage of its university resources, which are very considerable, as we are of ours. Just to take a simple example: in an essential area of computer science, that of software engineering, important theoretical underpinnings, logical programming, are more developed in Europe than here. Yet the European experts in logical programming are locked in universities and have very little communication with industry. The European computer industry has not taken advantage of an important resource which we envy in this country.

*Some concrete steps*

To return to our main question, what steps can be taken to develop a stronger research and development interaction between industry and the university? The answers would be self evident if we could focus on this problem with much greater depth and precision than is possible in the impressionistic overview to which this paper has to be limited. Some steps, however, suggest themselves at once. First of all, it is imperative that university and industry become better acquainted with each other. It may appear strange, but the fact is that they still do not know each other very well. If one looks at the dimensions of the problem, it is probably simpler for industry to get to know the universities than vice versa. There are, after all, no more than perhaps 100 engineering schools in this country that have substantial science and engineering research capabilities. Out of roughly a million engineers throughout the country only some 15,000 are in academic positions and probably only half of these are involved in research to any appreciable extent. A program on a national scale, by industry to establish systematic channels with each engineering school and each faculty member, appears quite possible.

A second step that must be taken, is to press for federal policies—fiscal policies—that would encourage R&D in industry and also encourage industry to take advantage of university research. At this moment the federal government seems to be going in the wrong direction. For instance, there is a strong push towards capitalization of R&D expenditures, rather than allowing them to be considered current expenditures. There is a whole array of bills in the congressional hopper that may appear to be of local importance but that will actually have significant influence on R&D in industry and on the relation of industry to the university. One example is the so called Minish bill, that would force companies in the defense establishment to compartmentalize their operation, so that profit in one component of their activities could not be used to offset losses in another component. A provision of this kind is bound to discourage risks in R&D. And yet, as we all know, R&D is intrinsically a very chancy process.

Canada is just beginning to give tax credits for R&D. This means that R&D becomes deductible from tax rather than from income. As a result, one can expect to see some shifts of research in our multi-national corporations toward Canada to take advantage of this policy.

Other obvious steps include a clearly formulated expression of basic research needs by many industries, and the vigorously pressing of the federal government to respond to such needs, in the same way that it has responded to pressures from

agriculture and from the health field. This point cannot be overemphasized. Only if we have a clearly expressed need of research priorities by industry, which may be quite different from the research priorities as perceived by the federal government, will we be able to have basic research programs in the university to respond to the needs of industry.

Lastly, the university must organize itself to respond to the needs of industry. In our study, which I mentioned earlier, of the relation among technology, the university and the community in Illinois, we concluded that many steps can be taken by the universities to respond to the needs of industry. But the universities must *want* to do so, and must find the financial resources necessary to do so. There is the corresponding need for organization in industry, in order to tap the university more effectively. There is a need for organization in individual companies, there is a need in industries on a sector by sector basis, and there is a need in industry as a whole to respond. Perhaps an NSF-like organization should be set up by industry in partnership with the university.

The cost and the effort that these, and other steps, require are not indifferent, of course, but the stakes are high, immensely high. We cannot afford to have industry and the university continue to interact weakly in R&D and in other areas that are vital to our national prosperity and, in the long run, to our very survival.

*Discussion*

AUDIENCE. In California, in the last six months, there has been a substantial movement at the state level to investigate members of the University's faculty for their actual consulting experience with industry. There is indeed a large consumer-type thrust that goes exactly the direction opposite to what you were suggesting; a suspicion is raised that any interaction with industry is somehow illegitimate. I think this is a basic problem facing the state universities where faculty-industry interaction is viewed as an illegitimate allocation of state resources.

Dr. BUGLIARELLO. I think it is a mistake not to encourage industry involvement by the faculty—within limits, of course.

Let me make two points. First, particularly when it comes to California, such a reaction is short sighted, because California, today, gets some 20 percent of the federal R&D budget while it pays a much smaller amount in federal taxes. This situation is the envy of every other state. If it discourages what has been a fruitful form of university-industry interaction, California may end up by killing the goose which lays the golden egg. Secondly, the university must work together with industry in making people perceive the nature of the research process and the fact that professors consulting for industry means jobs. My own institution has two campuses. One of them is on Long Island, which is an area of high technology. We are making enormous efforts to attempt to attract industry there, and one of the significant resources, of which industry is well aware, is that represented by Polytechnic and other universities. I believe that one needs to make whatever effort is necessary to convince people that an intelligent industry-university interaction can produce jobs. The experiences in several parts of the country, and particularly in California, have clearly shown this.

AUDIENCE. I think that this is a job that you need to add to your list, especially for state universities.

Dr. BUGLIARELLO. Without doubt.

AUDIENCE. Stanford University had, perhaps even still does have, an Industrial Research Affiliates Program. Are you familiar with it? Do you consider that to be a satisfactory model for industrial interaction?

Dr. BUGLIARELLO. An industrial research affiliate program is one of several mechanisms that can be used to foster interaction. However, there are relatively few such programs in existence throughout the country, and not all have been equally successful although the Stanford program has been very successful. Each company and each university obviously must.

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[From Technology Review, March-April, 1977]

## NEW WAYS TO BRING TECHNOLOGY TO THE MARKETPLACE

(By Jack W. Pearson, Lawrence Livermore Laboratory, University of California)

To begin, we must accept that the United States exists in a world of scarcity—that our resources are not and will not be adequate to do all we would like to do. So it will become more and more important to sharpen our criteria for efficient managment of the nation's natural, human and technological resources. As I hope

to show in this article, there has been far too little collaboration among government, industry and academia in commercializing our store of technology.

Our national productivity depends on a combination of labor, capital, and technology, and many economists contend that, of the three, the growth of technology has contributed the most to our past economic growth. Labor and capital are largely substitutable; that is, a rise in labor costs stimulates substitution of more capital-intensive production facilities. Technology is an independent input into the economy. It can offer productivity growth without being affected by either the labor or capital markets. Technology is also special in that it can be given away without losing it; that is, it can be transferred without the donor suffering any loss in the technology. This unique characteristic, plus the almost instant mobility of knowledge in today's world, give technology a potential for an enormous impact on productivity over a short time, in contrast to the relatively slow growth potential of labor and capital.

Importantly, while labor and capital affected productivity directly, technology cannot be applied directly. It must be commercialized, adapted, or processed into some useful product or productive capability. And it is here, I contend, that we are lagging. I should mention that my use of the term "produtivity growth" includes, not only materialistic growth, but "growth" in quality-of-life. This definition takes into account the legitimate concerns over the pollution and overcrowding that would result from a purely materialistic definition of the term.

### PLENTY OF TECHNOLOGY TO MARKET

If I am to contend that we are weak in our technology commercialization programs, I must first deal with the question of whether there would be enough technology to commercialize in the first place. Many observers, including myself, are convinced that we do, indeed, have a plentitude of technology. For instance, a comparison of receipts from technology royalties and licenses for 1960, 1965, and 1970, as shown on page 30, reveals that the U.S. provides to other countries far more technology than its receives. And the graph does not show all the technology exported in the form of products distributed by the pervasive spread of America multinational companies. In addition, federal programs to give incentives for greater private-sector technology innovation have revealed difficulties, not in the availability of advanced technology, but rather in technology marketing and distributing mechanisms.

To argue a national underinvestment in technology commercialization it is also necessary to demonstrate that resources now applied elsewhere can be more profitably used to enhance the technology factor of our national productivity. We must consider the advantages of a tradeoff because the real cost of any resource allocation is the opportunity lost somewhere else. We cannot, however, obtain direct empirical evidence that we would be wiser to invest more in technology commercialization. There is no way to set up a controlled experiment demonstrating the best division of technology resource allocation within our social structure. However, there is circumstantial evidence that we would profit from more investment in technology commercialization. This evidence, as we'll see, is obtainable from studies of how we have applied technology in the United States and from comparisons with practices in our countries that show productivity growth similar to our own. Especially interesting is the evidence, which we will discuss later, that the United States is falling behind the other industrialized countries in productivity growth.

### WHEN THE MARKETPLACE FAILS

Market forces will always provide a large measure of technology commercialization in a competitive market where an entrepreneur's benefits appear attractive enough to offset his risk. The impediments and disincentives to market allocation of technology resources are government-imposed in the form of regulatory and tax policy. Much technology development and application is not supported by market allocation, however, because the benefits are externalized, as social or public goods, to the extent that the return to an individual investor does not justify his investment.

For instance, the private sector is reluctant to support research and development in precision manufacture of machine parts, because its benefits are difficult to internalize, whether through patent protection or market capture. It is significant that there is an emphasis on precision technology in the state-subsidized manufacturing research centers common in all industrialized countries except the United States.

Such a poor showing in precision manufacture has definitely cost U.S. industry a competitive edge internationally. For instance, a few years ago the U.S.S.R. issued bids for proposals to all industrial countries for the construction of turnkey truck manufacturing plants at their huge Kama River complex. U.S. tool and die consortiums that formed to respond to these bids for proposals declined to bid high-precision production plants, such as one producing diesel fuel-injection assemblies. The U.S. consortiums did not have at hand the precision technology needed to assure the required quality control. So, the U.S.S.R. production plant contracts for precision products typically went to Sweden, Germany and Japan.

Automated manufacturing represents another area of lagging technology commercialization with enormous economic potential. Here, too, the combination of risks and externalized benefits inhibit private investment. The forerunner of automated manufacturing, the numerical control (NC) machine tool, was developed in the U.S. during the early 1950s as a result of the growing need for more accurate fabrication control of complex wing shapes needed for jet-powered aircraft. The Air Force funded efforts at M.I.T. which, with industry, developed the first NC machine tool. When the growing use of NC tools created a bottleneck in the NC programming, the same government-university-industry team developed the architecture for a generalized NC language called automatic programmed tool (APT). Under sponsorship of the Aircraft Industries Association, the basic APT program was completed by 1960 and has since undergone further refinement at the Armour Research Foundation of the Illinois Institute of Technology.

As a result of this cooperative effort, the U.S. became a world leader in the hardware and software of this important new manufacturing technology. At that point, the development team disassociated, and since then the U.S. has lost leadership in the development of automated manufacturing to Japan, Norway, Germany, France, and Russia, with Japan coming closest to having the first fully automated factory. The automated manufacturing research and development efforts in these other countries are based on a similar collaborative arrangement among government, academia, and industry.

### EVIDENCE OF UNDERINVESTMENT

I realize that I have not automatically established the case for national underinvestment in commercializing technology merely by showing that the market focuses on internal benefits of technology commercialization and largely neglects external benefits. However, illustrating this neglect shows where the possibility of underinvestment lies. More important to my charge is that the fraction of GNP devoted to research and development since 1967 has declined, and that government-supported civilian research and development neglects development, especially in comparison to military and space work. In government-sponsored space and defense work, basic research comprises 9.7 percent, and development 73 percent. But in government-sponsored civilian-related work, research comprises 27 percent, and development only 31 percent.

Costs of development or applied research and development are always much larger than those of basic research. So, the fact that development occupies such a small portion of civilian research and development suggests at least an internal imbalance in how funds are allocated to technology utilization for public goods.

It should also be noted that, of all industrial countries, the U.S. government, by far, spends the most on research and development. But this investment is heavily concentrated in space, defense, and nuclear energy, with relative neglect of civilian industry research and development, in contrast to other industrial countries where civilian research and development is favored.

### AN UNFAVORABLE COMPARISON WITH OTHER COUNTRIES

Comparisons of U.S. technology utilization with that of other countries support the argument that our technology commercialization is lagging.

Over the last ten years four European nations, Switzerland, Sweden, Norway and Denmark, have risen to lead the United States in per capita income, with Germany close on our heels and Japan due to pass us within the decade. Our national productivity growth rate is continuing to decline. Part of the greater per capita income in the Scandinavian countries results from a larger percent of population employed, but much of the ascendance of other countries is due to a more favorable productivity growth rate.

During 1974, U.S. productivity growth in manufacturing continued the lagging performance revealed by the longer-term averages of 1966–1973 shown on page 32. Estimates for the first half of 1974 shown on page 32. Estimates for the first half of

1974 indicate that productivity in major industrial countries abroad, except in the United Kingdom, rose more than in the United States. From the first half of 1973 to the first half of 1974, output per man hour rose about 1 percent in the United States while rising over 9 percent in Japan, 6 percent in France, 4 percent in Germany, and 2 percent in Canada.

Thus, there are reasons to look for economic imbalances in the United States that work to prevent a competitive productivity growth rate.

### TECHNOLOGY THE BEST HOPE

Of labor, capital and technology, the technology sector of our economy clearly offers the most hope for future productivity gains. Over the last half-century, labor productivity growth in the United States has resulted primarily from the entry of surplus farm workers and in more recent years, from the entry of women. However, this source of growth has natural limitations for the future, especially considering the declining birth rate. Capital formation is limited by profit prospects and interest-rate controls on savings. Thus, capital growth is increasingly pinched by the decline in corporate profits and the lowest private savings rate of all industrial countries.

In addition, inflation acts to prevent capital formation. It chips away at real savings available for investment and overstates business profits. This eroding of private capital formation is magnified by the progressive tax system that—if inflation continues without tax rate adjustments—will eventually place everyone including the lowest wage earner in the highest tax bracket. Inflation has been the most politically realizable source of additional federal revenue. It will be tempting for government to stand by and let this method of increasing revenues continue. Because much of federal revenue is devoted to the distribution of revenues for immediate consumption, inflation acts as an illicit tax that stimulates present consumption at the expense of capital formation.

For every dollar of return on capital investment in the U.S., 75 cents goes for labor costs. In spite of this division of return on capital favoring labor, labor political policy emphasizes income distribution—a policy of trying to divide the pie more equally—even though clearly, labor gains most from policies that increase the size of the pie through inreased capital investment.

These limitations on labor and capital leave the technology factor, which has also been declining, as the best hope for increasing the U.S. growth rate. In recent decades the traditional concept of productivity derived from relatively static factors of land, labor and capital has given way to the more dynamic labor, capital and technology concept. But the technology factor has not had an easy acceptance within the economic community. The struggle to categorize productivity factor inputs that, to me, appear as technology, is evident in contemporary economic literature. If we define technology as all mechanisms and procedures used to implement policy, then detailed calculations of economic data show that technology is responsible for about 70 per cent of our economic growth from 1930 to 1972. Moreover, our overall growth lagged behind other industrial countries during the entire post-World War II period.

### WHY OTHER COUNTRIES LEAD

Let us assume that our poor showing in productivity growth rate comparisons with other industrial countries is valid evidence that there are better ways to allocate resources to technology commercialization. Then we should ask what characteristics of the other industrial countries have allowed them to catch up to and in some cases surpass the United States in per capita income. I believe that there is ample evidence that modern technology assiduously applied to the civilian industries deserves a large share of the credit for their greater growth rate. True, part of their record is surely due to the process of catching up with the long-standing United States technology lead. But much of their growth rates appears to be inherent, with no indication of recent diminishing returns in the trend lines that would be expected if their process were primarily one of catching up.

The circumstances are similar to those of Great Britain and Germany during the period 1850 until World War I. During this period Great Britain lost productivity leadership to Germany as a result of Germany's more rapid adaption and adoption of industrial technology, even though a good part of the advances in technology of that period were of British origin. To apply this theme to the subject at hand, one can speculate that failure of the U.S. to create and exercise an effective industrial technology delivery system, both on an absolute scale and relative to that of Japan

and other industrial countries, is a significant factor in our slowing productivity growth rate.

The countires that seem most favored in their productivity growth rate have all somehow, within their social structure, found a way to achieve a close working harmony among the institutional elements important to technology development—government, academia, and industry. Japan, consistency with the highest growth rate, is monolithic in this respect. In contrast, the U.S. and Great Britain both suffer an almost adversary relationship among these elements.

In several industrial countries, political difficulties tend to obscure and, to a large extent, negate the benefits of close institutional collaboration. Even so, the presence of these benefits is a principal finding of a recent study by the General Accounting Office (G.A.O.) of manufacturing productivity in other industrial countries. The study showed an average capital investment in manufacturing industries of $600 per worker in other industrial countries versus $200 per worker in the United States.

The study also revealed that 97 percent of U.S. factories employ less than 500 people, meaning that they would particularly benefit from a service to help them implement new technology; larger companies have such services in-house. However, the study found that these companies were not nearly so well coupled to to universities and other sources of technology commercialization aid as were small companies in other countries.

G.A.O officials also pointed out that the European education system contributed to rapid technology commercialization. European higher education is different from ours in that anyone who wants a master's degree must have an industry sponsor, who may or may not finance the effort. This forces bachelor-level graduates to make their mark in industry before they can add to their formal education. The doctoral candidate must also have government or industry sponsorship and will usually have six years to solve the problem used to obtain sponsorship. Also, professors normally hold their posts for four years, then must be accepted by industry or government. This turnover in universities and the focus on applied technology to obtain higher degrees forces education relevancy and technology innovation. It results in a rotation of personnel among government, industry, and academia that contributes to a collaboration of all elements toward greater productivity.

The G.A.O. study also mentioned the widespread European "productivity centers" as important factors in technology commercialization. These centers, founded under the Marshall Plan after World War II, are governed by a board consisting of representatives from government, industry and academia. When approached by a private company with a new product, they perform productivity analyses on the new product, cost analyses, capital cost projections, and other manufacturing studies. Besides the value of this information in itself, the productivity center's analysis carries a great deal of weight with bankers, who are more ready to lend the manufacturer needed capital when he is backed up by the center's independent analysis.

Even if foreign countries' social structures are central to their greater growth rates, we cannot reasonably suppose that a social structure peculiar to another country can be imported to the United States to implement a more fruitful collaboration of institutions. It is, however, reasonable to ask whether there is an American example of close working harmony among government, academia, and industry in achieving a national goal where the primary benefit is in the form of public goods, and if so, whether the collaboration has been effective. Examples of benefits that come to mind are the machine tool technology mentioned earlier and the development of atomic energy, which resulted from the fruitful collaboration of government, industry and academia. But these, it may be argued, represent single-mission efforts born within a national crisis environment.

### THE FARMER'S ALLY

More to the point, what institution do we have within the American social structure that fits the need for broad industrial productivity growth? Do we have an example of a collaborative effort that has been effective in solving millions of productivity problems, large and small, on a continuing basis? One excellent example is the Cooperative Extension Service operated by the nation's land-grant colleges to serve their regional agribusiness communities. This program began over 100 years ago at land-grant colleges and took on its present characteristics with the Smith-Lever Act of 1914 that created a network of local advisors or county agents, as they are sometimes called. The advisors are skilled agricultural experts who go into the agribusiness community and work with producers and processors in implementing the latest technology.

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Of course, agriculture is significantly different from general manufacturing in terms of user group homogeneity, proprietary jealousies and capital needs. It is too simple to say that the same approach that works for agriculture could be applied to industry in general without modification. Also, it is far from clear whether the American agriculture extension model, the European productivity center model, or, perhaps some other arrangement, would serve as the best technology delivery system complementing market allocation within our social structure. Even so, it is worthwhile to examine the fundamental operating characteristics of our university-directed agriculture cooperative extension services.

For one thing, it is successful. Much of the miracle of American agricultural production is attributed to the extension programs of the land-grant colleges. And, because they are essentially voluntary programs, they do not violate American concepts of free economic choice. Of every dollar spent on agricultural research in this country, 50 cents is spent on its delivery to those who can use it. In other areas of scholarly research, the average expenditure on delivery of new knowledge is about 1 percent of expenditures on the research itself.

As you can see on the facing page, agriculture has the best growth rate of all the major economic sectors in the United States, and this is in the face of a steady decline in labor input. For example, in 1966 farm labor required 6.8 percent of total U.S. man-hours, while in 1973 it required only 5.2 percent.

## THE AGRICULTURAL TRIAD

In the nation's agricultural cooperative program, the government identifies goals and supplies the funds needed to produce the public goods. The university extension controls research and development, and supplies the trained manpower needed to service industry and maintain its own research and development and training function. Industry implements new technology within its productive process by incorporating technology directly from the extension service and by using the contributions of university-trained manpower.

The university's critical role is to provide a commercially neutral, high-credibility management to allocate resources for public goods technology development and commercialization. The agricultural research and development budget, within academia and at the experiment stations, aims at addressing the high-priority problems of local agribusiness, not at providing interesting research projects for professors.

The university sometimes acts as a buffer between government bureaucracy and industry, heading off government actions that would be counterproductive within the local area. A large university working through the governor's office, the state's congressional delegation or through community leadership, will usually have more politicial clout to protect local interests than will the principals of some harassed enterprise. Thus, it provides the micro-economic viewpoint within the context of a national program.

The university is also able to manage funds from multiple sources. The California Extension Service, for instance, obtains approximately 50 percent of its public funds from the state, 25 percent from the federal government, and 25 percent from local government. In addition, industry voluntarily contributes a percentage of identified benefits in the form of donations to the Extension Service.

The university also provides an important continuity of purpose and direction, and thus supports the long-term viewpoint within a political and economic environment that rewards short-term gains.

In this university-government-industry triumvirate, industry's important role is to implement change. Rapid adaptation to changing needs is something the business and corporate body does well and that neither governments nor universities can do. A modern business enterprise is the political entity best able to adapt to change and make the changes immediately part of our economy and culture through the mechanism of the open market. The system of rewards and penalties inherent in a competitive market environment ensures rapid response to the testing of efforts to exploit technology.

## WHAT TECHNOLOGY TO MARKET

If we accept the Cooperative Extension Service model of how to give business incentives to commercialize technology, we must ask how a technology extension service would decide where to apply its resources and where to allow the market to function independently. Such decisions would be mainly pragmatic. Any high-priority problem would be a fair target for a technology extension service to address, with the highest priority given those problems whose solution promises a broad industry-wide productivity improvement. The technology extension service would complement normal market allocations and still allow the market to function freely

where the potential profits are adequate to attract investment. Market adjustment, we assume, will be adequate for most needs, and problems amenable to market adjustment will be resolved before becoming high priority problems for extension address. However, many times an extension service would have to act as a quick-reaction scheme when the market reacts slowly to a problem. For instance, a few years ago when restrictions in California were legislated on importing Mexican stoop labor for field crops, there was created an almost overnight need for a low-labor-use mechanical tomato picker, which was developed through a cooperative industry/extension service effort. To aid this development the extension service very rapidly bred a tomato with a skin tough enough to be handled by the picker.

Such a public agency working within a predominantly market environment must be very sensitive to its economic role in complementing market action, which in turn, requires a very close coupling with industry. The close coupling is provided by the extension offices of the local advisor.

The local agricultural advisor working out of county offices is the key link between industry and the university in the cooperative extension service. He works both ways, spoon-feeding technology into the farm industry and relaying industry needs back to academia.

In contrast, general industry feeds back its needs to academia by hiring the graduates of universities. Such a feedback is far too general to help determine research and development direction and structure curricula. The lack of close feedback from general industry to academia in the United States may explain why there is almost no manufacturing engineering taught in American universities. In contrast, manufacturing engineering (not to be confused with industrial engineering) is emphasized in other industrial countries. For example, France produces the concept of productivity at the junior high school level and discusses such advanced technology as Computer Aided Design/Computer Aided Manufacturing in the high schools.

My own studies of the effectiveness of technical information systems confirm the value of the active consultant in technology transfer. Large information systems that lack the coupling service of a professional worker between the data bank and the user become almost impotent in transferring technology. In contrast, the successful information systems focus on a special class of problems and provide person-to-person working arrangements within the chosen field. This process is well developed within the Extension Service. A typical career path for a professional in the Extension Service is to spend his academic years learning his field and his research years developing technology within an experiment station; then, somewhere between the ages of 40 and 55, when he begins to be more interested in applications of his learning, he is groomed as a local advisor to be stationed out in the community.

## THE TECHNOLOGY EXTENSION AGENT

A local advisor to general industry would be likely to have a more difficult job than his counterpart in agriculture because of the greater diversity of technical and business challenges. The problems of coping with such a diversity have been encountered by the few university extension services that address general industry problems, such as the Engineering Experiment Station of Georgia's Institute of Technology and the Institute of Public Service of the University of Tennessee. Experience shows that the local advisor in a general industry service is still a key element, but he will function relatively more as a router of problems and require a broader multidisciplinary backup.

A few agricultural extension services have begun to expand their role to encompass general industry, such as the Missouri Cooperative Extension Service. Missouri farmers welcomed the broader business and industry competence of the well-established agricultural service to serve general industry, because the typical extension client has changed from the family farmer to the corporate producer and processor with broader industrial problems of finance, planning, marketing, and community relations along with a more complex technology.

Interestingly, general manufacturing, as well as agriculture, is included in the land grant college charter that is the legislative foundation of the state university's aid to agribusiness as specified in the Morrill Act of 1862. Only tradition has maintained the agricultural focus of the Extension Service. The predominantly agrarian economy of 1862 and the Hatch Act of 1887 that provided for experiment stations, plus the Smith-Lever Act of 1914 that established the extension service served to focus university technical aid effort in the beginning on agriculture.

## PAST FAILURES, FUTURE SUCCESS

There have been many attempts, only marginally successful, by the federal government to enhance technology commercialization by establishing technical information systems. These efforts to make available shelf-technology from government research include the State Technical Services Act Programs begun in 1965. This system was designed to link universities with regional industry, but was denied further federal funding in 1969, allegedly for want of adequate results, although many states have continued the effort on their own. There are arrays of technical information centers funded by N.A.S.A., D.O.D. and the National Technical Information Service of the Department of Commerce. The Energy Research and Development Administration (E.R.D.A.) funds efforts by its principal research and development contractors to make E.R.D.A.-funded research and development information available for the asking. Efforts to publicize the technical information services and identify data bank contents vary widely from center to center.

Technical information data banks are needed and important but are less than ideally effective without an active user coupling mechanism. It seems significant that the N.A.S.A. technical information centers have evolved from passive centers that supplied on request whatever documents and reports resided in the data bank, to the kind of effort exemplified by the N.A.S.A.-funded New England Research Application Center which now has university affiliation and local advisors to help identify problems and to help potential users interpret pertinent information from the bank. Also, because federally funded off-the-shelf technology is rarely suitable for commercialization as is, some adaptive engineering, as provided by experiment stations, is needed to bring this technology to the threshold of commercial attractiveness. Lack of an adaptive engineering capability is a handicap in obtaining full commercial utility of a technical information center.

Another technology delivery system in the U.S. is the case study kind exemplified by the Materials Processing Institute at Carnegie-Mellon University. This approach relies on finding real industrial problems for address by engineering students and teachers. The manufacturer supplies the problem and benefits from a case study of his problem. The case study approach has considerable merit, especially for business management problems. A major problem is that industrial problems do not usually fit into the neat time-mold of the academic semester or quarter. Also, academic compartmentalization makes it difficult to provide a multidisciplinary approach to what are usually multidisciplinary industrial problems. As a technology delivery system, the case study approach contributes more to the educational process than to technology transfer.

## FIVE MUSTS FOR A TECHNOLOGY SERVICE

A Lawrence Livermore Laboratory study of technology commercialization services in the U.S.—including university affiliated extension services, state and regional economic development efforts, and the N.A.S.A. and D.O.D. technology transfer programs—shows that five interacting operating elements are important to success:

*University affiliation,* which, in addition to the management services and the regional or micro-economic viewpoint discussed previously, provides a multidisciplinary resource bank and couples government and industry. The university also nourishes the service with a steady supply of trained personnel.

*Experiment stations* where research and development are conducted in support of both industry and academic purposes. An important role of the experiment station is to do the applied research and development necessary to bring the knowledge acquired from basic research to the stage where industry feels confident in proceeding with commercialization efforts. The experiment station is also the melding arena where multidisciplinary task-oriented teams are formed from the discipline-oriented resources of the university.

*Resident experts* who respond to local advisor requests with information from their own knowledge, contacts with others in their field, and access to today's large network of national and international technical information systems. They also do research and development within the experiment station in response to both specific and general industry needs.

*Local advisors* who provide limited on-the-scene information, feed back problems and interest trends to the extension service management and follow up technology transfer efforts. They act as the marketing arm of the service in establishing identification and rapport between industry and the service.

*A coordinated education and training program* to educate the technology recipient to the level that smooths the path for technology transfer. This is another reason why university affiliation is important. A common misconception is that the agricul-

tural service has been successful because well-trained agriculturalists were working with the relatively untutored farmer who was, thus, receptive to their ideas. On the contrary, this was an earlier handicap that has all but disappeared in today's agribusiness environment, which typically includes university trained extension clients, many of whom hold the M.B.A. as well as degrees in agricultural science.

Besides the above operating elements, a special kind of management is needed to operate a technology delivery system at the state-of-art level. Most businesses and government agencies are task oriented which is necessary to manage a multidisciplinary approach to goals. Universities are discipline oriented, which is necessary to maintain state-of-art quality of a discipline. An extension service, however, needs to be both. It must be multidisciplinary in its approach to problems, yet maintain state-of-art quality in the pertinent disciplines. Combining the best of both organizational orientations requires almost a third world of matrix management. As I've indicated earlier, a technology extension service must also have a philosophic sensitivity to its role in complementing (not supplementing or competing with) a market environment by providing technology benefits that purely market allocation leaves wanting.

I have explained the workings of the Agricultural Extension Service at length, not necessarily to offer it as a model, but to call attention to the need for a system that is comprehensive and structured enough to provide a supply and demand approach so that needed technologies *will* be developed.

Certainly, more effective technology commercialization through a more collaborative government, academia, industry social structure could enhance national productivity. But I also believe that an important additional political benefit lies in the social good that will naturally result from a closer working relationship among key institutional elements, where the goals of each are directly seen as achievable through voluntary cooperation. At the heart of this cooperation lies a better opportunity to define the best economic roles for our principal institutions.

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## State Technical Services

(By Walter A. Hahn and Rosemary A. Chalk, Science Policy Research Division, Congressional Research Service)

The State Technical Services Program was preceded by the Civilian Industrial Technology Program, originally proposed by the Department of Commerce Assistant Secretary Hollomon in 1962. The CIT Program envisioned the establishment of an effort (to upgrade the technological competence of "backward" medium and small business firms in industrial sectors with comparatively low rates of R&D activity). In 1964, an experimental and limited program was authorized by the Congress in textiles and apparel.

Subsequently, the Office of Textile and Apparel Technology was established in the National Bureau of Standards with a total budget of $1.625 million. This office was authorized to award contracts and grants to firms, trade associations, and educational institutions to promote invention and innovation in textile and apparel technology. This program was discontinued at the end of 1969 when it was felt that its major objectives had been achieved.

Three important lessons were learned from these programs which would appear to apply equally to any new STS-type of activities.

First, technology transfer is largely a teaching and learning process on a face-to-face level for firms with low rates of R&D activity.

Second, it is necessary to establish "creative organizations" to promote technology transfer and utilization among these types of firms.

Third, don't label any section of the economy "backward" if you want Congressional support for it.

The State Technical Services Act of 1965 (also initiated by Hollomon) (Public Law 89-182) called for the promotion of economic growth by accelerating dissemination and utilization of scientific and technological knowledge by industry. Unlike CIT, the STS Program operated on a formula matching grant basis with each of the States and territories, through a single agency designated by the Governor. The basis STS Programs covered grants in initial planning, demonstrations, educational programs, information services, field services and referral services. Additionally, there was a Special Merit Program also operated on a matching basis, and used by OSTS for special studies and experiments in technology transfer.

OSTS was funded to a total of $20 million during its existence, including close-out costs. This figure includes only Federal appropriations and does not take into account matching State funds. OSTS through the use of relatively small amounts of

money, increased the viability of technology transfer to industry for a fairly wide range of programs, particularly in medium and small-sized industry. OSTS not only identified the types of information and services needed by industry, but equally, the most effective techniques for technology transfer.

The Johnson Administration's fiscal year 1970 budget requested $5.8 million for STS. This was reduced to $290,000 in the revised (Nixon) fiscal year 1970 budget pending an evaluation of the program. Upon positive evaluation by A. D. Little and by in-house analysts, a $5.0 million fiscal year 1970 supplemental request was made to the Congress along with a request for $8.0 million in fiscal year 1971 by the Department of Commerce to the (then) BOB. The Congress "zero-funded" the STS fiscal year 1970 supplemental and the Administration never submitted the fiscal year 1971 request. The effort to withhold funds for the STS program was led by Congressman John Rooney (Brooklyn, N.Y.) who had long fought to eliminate the program. The STS Program was ended by DOC in calendar year 1970, with OSTS formally abolished on April 1, 1970. STS-funded projects for fiscal year 1969 were allowed to continue to completion. Fiscal year 1970 funds were used only for staffing and phase-out costs.

*Evaluation of the STS program*

There have been several studies of the effectiveness of the original CIT and STS functions. The major ones were reports by the Public Evaluation Committee chaired by Carl Elliott[1] and the contract study of Arthur D. Little Inc. of October 1969.[2] In addition were various other analyses by State, academic and association groups, and the report of the FCST Committee on Intergovernmental Science Relations (CISR).[3] These evaluations have built a consensus on the following points:

There is a proper governmental function to be performed in the transfer of the technology from publicly supported R&D activities and from other "generally available" (non-classified and non-proprietary) sources to the private sector.

Federal, State (and more recently local) governments each have both active and passive roles to play in technology transfer. The private sector should be expected to contribute as well as benefit.

Technology transfer actions return to their sponsors, and to society-at-large, benefits (in the form of increased productivity and tax revenues) in excess of program costs.

Federal Government leadership, systems research and design, and "catalytic" sustained partial support are necessary for a viable nationwide effort.

A vigorous Federal, State, local government (plus private sector participation) technology transfer program can be a significant, stimulating, and sustaining force in technological, economic and social enhancement.

The ADL Report specifically noted that the STS program had been most helpful to small and medium sized firms, providing useful technical services to these firms, who would not or could not pay for such services. The report concluded that STS provided a useful and economic service which substantially benefited the Nation, justifying continued Federal support. It also stated that an important effect of STS was the increased awareness by program users of external technical resources and how to apply them. The Elliott Report emphasized the particular value of the regional and interstate projects of the STS, which had the economic advantage of pooling resources on common activities and significantly improved communications between interstate participants of STS programs.

These same evaluations also listed several weaknesses of the STS program, which included the low level of available funding. The uncertainty about funding often made it difficult to retain the very able people who had been attracted to the program and impaired recruitment of others. The Elliott Committee commented that this hardship was particularly serious in those smaller and less industrialized States which stood to gain the most from the STS program.

There was a tendency for many States to provide technical services directed towards solving problems of a regional character on an independent basis. This led to some duplication of effort and to dilution of the effectiveness of the services provided. Independent efforts in some cases often weakened communications between States. ADL noted that OSTS had a unique contribution to make in such communication, and this could be improved to facilitate more complete exploitation of useful results and techniques.

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[1] "Growth Through Technology." Final Report of the Public Evaluation Committee for the STS Act of 1965. Presented to the Secretary of Commerce, Nov. 14, 1968.

[2] "Program Evaluation of the Office of State Technical Services." Report by Arthur D. Little, Inc. to the Department of Commerce, Office of Program Planning. Oct. 10, 1969.

[3] "Public Technology: A Tool for Solving National Problems." Report to the Federal Council for Science and Technology by the Committee on Intergovernmental Science Relations. 1971.

*Primary recommendations made concerning the STS program*

*Arthur D. Little study*

1. The program should be retained and Federal support continued.
2. Problem-solving services to industry which do not participate in federally-sponsored R&D programs because of small size or nature of industry should be the central activity of the program.
3. Field services which are oriented towards problem-solving should receive increasing emphasis through increased budgets and more personnel.
4. Education, information services, and demonstrations should be de-emphasized and only used as discretionary activities in support of need-oriented field services.
5. Federal funding levels should be increased gradually in a manner which permits new personnel to be adequately trained.
6. The funding formula for the States should be revised and expanded to take into account need factors, as well as performance.
7. The DOC should establish regional offices for improved communication and coordination of activities between the States.
8. The State directors should have more flexibility in the use of funds.

*Elliot report*

1. DOC shold seek an extension of the authorization of funds for STS for an additional three years, and should make every effort to secure increases in funds.
2. DOC should encourage and help the States to make use of the existing information centers and centers of specialized excellence in their dissemination activities.
3. The Act should be so administered as to encourage more regional and interstate programs.

Despite these positive evaluations, STS was ended by DOC in calendar year 1970, due to zero-funding by Congress of the requested $5.0 million supplemental funding and the lack of fiscal year 1971 request for funds. The Senate had approved the full supplemental amount sought by the Administration; Senator Prouty stated that "every piece of hard evidence indicated that STS had one of the most effective cost-benefit ratios of any program in the Federal Government." However, Representative John J. Rooney, chairman of the House Appropriations Subcommittee for the State, Justice and Commercial departments, held the program in low regard. He contended that STS activities should be handled by other programs of the DOC, including the Economic Development Administration and the Office of Field Services.

The STS program may also have suffered from being only one of a number of Federal conduits for technology transfer, to say nothing of the normal commercial processes of technological innovation. And although STS had often been compared to the Agricultural Extension Service, it was not backed by Federal programs of research relevant to specific industrial needs.

*Present situation*

The legal authorization for STS expired on June 30, 1971. At present, there is no STS organization within Commerce nor are there any funds directly appropriated for STS-type activities. However, several units within DOC and within the Federal and several State governments are continuing or have initiated programs which propose to transfer scientific and technical knowledge and other related services to industry, the States and local government.

These programs may be grouped in various ways, but all share the common element of putting R&D results to practical use. The more well-known examples are the NASA Technology Utilization Program and the Agricultural Extension Service. Smaller technology transfer programs exist in Environmental Protection Agency and the Small Business Administration. Various "clearinghouses" of technical information also have developed, including the National Technical Information Service in Commerce and similar functions in the AEC and DOD. An experimental technology transfer effort was recently established by the National Science Foundation. This program, the Federal Laboratory Liaison Program, is located within NSF's Office of Intergovernmental Science Programs. As its name implies, it is involved in the transfer of technologies developed in Federal Research Labs. Specifically, this program works with a consortium of 15 DOD labs and is promoting the application of lab technologies to the solution of civilian, domestic problems. NSF's program is essentially a one-man effort; its Director functions as a broker, serving as a coordinating link between the Federal, State and local government agencies and organizations and the DOD labs.

Finally, "technical assistance" grants are provided through the Economic Development Administration program in Commerce, and NSF provides some grant money for technology transfer research programs through its Office of Intergovernmental

Science and Research Applied to National Needs Programs. This brief compilation does not represent a complete inventory of the technology transfer efforts within the Federal Government. But it is an attempt to indicate the various directions and locations of some of the present efforts.

OST has indicated that under the auspices of the Federal Council on Science and Technology there has been an ad hoc inter-agency group studying technology transfer for the past year or longer. A number of agencies, including Commerce (NTIS and EDA), NSF, EPA, and the Legal Enforcement Assistance Agency, are reported to have prepared and exchanged "position papers", summarized by Mr. Goddin in the Treasury Department's research organization. The present leader of this inter-agency group is Mr. Phillip Schaffner. Mr. Schaffner's superior, Deputy Assistant Secretary of Treasury for Research is Dr. Wilson E. Schmidt; he states that "good progress is being made, everything is fine," but refuses to release any of the interim documents. No schedule for completion of the studies has been stated. One gets the impression that technology transfer is a low priority and uncoordinated activity in the executive branch.

*Proposed legislation*

Several bills have been introduced to the House in the 92nd Congress which intend to reestablish the STS program within Commerce. These include H.R. 6976 (introduced by Representative Morse for the entire Massachusetts delegation on March 30, 1971), H.R. 7414 (introduced by Rep. Morse and 22 others on April 7, 1971) and 3 other identical bills (H.R. 8428, 8779, and 9905). These five bills all propose to revise and extend the State Technical Services Act of 1965, with several amendments including: (1) That the Act be extended through fiscal year 1974; and (2) that municipal governments be eligible for technical services under the Act. A sixth bill, H.R. 7110, introduced by Rep. Moss of California, proposed to extend STS for 3 additional years. All six bills have been referred to the Interstate and Foreign Commerce Committee in the House and no action has yet been taken on any of them. No legislation has been introduced into the Senate in this Congress.

Senator Jennings Randolph, chairman of the Subcommittee on Science and Technology, Select Committee on Small Business in the Senate has been a consistent supporter of State Technical Services, and held hearings on technology transfer in the Senate in 1970.[4] The subcommittee's interest also extends to technological utilization in relation to small firms.

*New forces urging technology transfer programs on the State level*

Several recent public statements have highlighted the need for new arrangements to promote technology transfer. The private sector and the Federal Government have traditionally been the primary actors in these arrangements; however, current comments often mention the necessary role of including State governments in the process, and in some cases, making these institutions the administration force for technology transfer. A few extracts follow, which indicate some of the areas of current thinking:

The President's Message on Science and Technology (March 16, 1972) included several statements on the need for new institutions in technology transfer: "* * * we must appreciate that the progress we seek requires a new partnership in science and technology—one which brings together the Federal Government, private enterprise, State and local governments, and our universities and research centers in a coordinated, cooperative effort * * *.

"I believe the Government has a responsibility to transfer the results of its research and development activities to wider use in the private sector * * * the new incentives programs of the National Science Foundation and the National Bureau of Standards will seek effective means of improving and accelerating the transfer of research and development results from Federal programs to a wider range of potential users."

A recent position paper offered by the National Governors' Council on Science and Technology[5] includes the following statement:

" * * * a majority of problems and opportunities to benefit from the introduction of technological innovations exist in individual companies or in State and local governments. A major reservoir of technical capabilities consists of faculties in public and private universities. A national program should assign appropriate tasks to each of these groups.

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[4] U.S. Congress. Senate. Select Committee on Small Business. Technology Transfer, hearings before Subcommitttee on Science and Technology. Part I, 91st Cong., 2d sess. Feb. 10, 1970

[5] "Technology Applied to National Needs." Position Paper of the National Governors' Council on Science and Technology. Oct. 22, 1971.

"An examination of experience under the State Technical Services Act of 1965 shows that field service programs were most effective in solving problems. Many more benefits could have been achieved had more people known about the program, and had there been greater abilities to modify developed technology for new applications."

The national meeting of the American Society for Public Administration held in New York (March 22–24) highlighted science and technology in a series of sessions. Technology transfer and its administration generated some discussion, and aside from the ambiguity of the term, consensus appears to be growing on three points: (1) broad-scale "pushing" technology developed for a specific purpose toward unspecified new uses is a very low pay-off activity, (2) storing (on paper or film) information about once-used or thought-of technology in clearinghouse is a necessary but insufficient element of technology transfer, and (3) technology transfer can occur once a need or opportunity has been recognized and some kind of "eyeball-to-eyeball" chain of events is launched to link the need with either the solution or the solver.

Participants noted that there is also an overwhelming similarity of problems faced by literally tens of thousands of local governmental units but no *one* of which has adequate financial, technological, or institutional means to solve them. By what means can increased standardization of the products of "public technology" be analyzed? How can markets be aggregated to make them economically attractive to private initiative? How can so-called generic problems be resolved so that the solutions are broadly available?

Finally, several speakers at the White House Conference on the Industrial World Ahead (Feb., 1972) emphasized the increasing importance of technology transfer. Dr. Simon Ramo stated that: "Despite the potential of economic and social gain inherent in the productivity increase and greater flexibility the technology would provide, the speed with which this kind of technology can come into being is greatly contingent on new organizational teaming of corporations and government." Dr. George Kozmetsky noted further that "The technology transfer process entails a large number and variety of institutions and organizations and flows through a large number and variety of channels." He then elaborated a series of steps which must be included in any design of policies or institutions to administer this process. Kozmetsky concluded that the single most powerful factor affecting the technology transfer process is the pull of demand.

*Elements of a Federal/State technology transfer program*

For convenience in considering policy and program options, Federal activities for technology transfer may be considered in three categories: information services; technology transfer research, experimentation and demonstration; and field services.

*Information services.*—Many state activities in information dissemination antedate STS. Industry information service programs have existed in Georgia, North Carolina, Iowa, Pennsylvania, New York, Texas, etc. These usually have been operated through Land Grant Colleges as extension-type activities. Federal information services in technology transfer program are often based on the concept of total information systems. The elements of these systems comprise information clearinghouses, library services, computer networks, education and training.

The largest Federal scientific and technical information programs are operated by NASA, DOD, and AEC, although the information activities of NASA and AEC have been considerably reduced. These services are intended for internal use, other Federal agencies and contractors. Reports generated with these systems however are made available to the general public through the National Technical Information Service within DOC.

Commerce's reorganized NTIS is adequately meeting some aspects of the information services needs of technology transfer. Many feel that the DOC through NTIS can also make a significant contribution to technology enhancement in other agencies and governmental levels and, of prime importance, in the private sector if cooperative management and fiscal arrangements can be worked out among the agencies.

*Research and demonstration.*—A Federal technology transfer program must concern itself with the dynamics of knowledge utilization as both a process and a system. This includes research, development, testing and, experimentation in technology transfer itself as was done in the STS Special Merit Program. However, the new cooperative arrangement between NSF and Commerce (National Bureau of Standards) plans to develop knowlege of technology transfer processes in its research program. The Experimental R&D Incentives Program will include a relatively small number of highly structured experiments which will be directed at establishing a data base for future policy decisions.

This program will be reviewed by the NSF-Commerce Coordinating Committee, co-chaired by the Assistant Secretary of Commerce for Science and Technology and the NSF Deputy Director.

Technology transfer research will also likely be carried out through NSF's Project RANN and the Office of Intergovernmental Science Programs, NASA through its Office of Technology Utilization has been conducting research in the mechanisms of technology transfer for nearly a decade, NASA's program orientation has been primarily industrial, although there has recently been a shift in emphasis to include the needs of local government. AEC's programs in technology transfer research have been completely eliminated.

Some successful experiments in technology transfer have also been conducted by the States themselves. Perhaps the most notable of these is PENNTAP (The Pennsylvania Technical Assistance Program).

*Field services.*—These activities are generally considered the highest pay-off area of technology transfer activities and are almost non-existent federally, sporadic among the States, and absent at the local level. A revival of this proven activity, whether under the STS label or that of a new program, presents an opportunity for an initiative with a high probability of immediate and sure benefits to the economy.

Of these three categories in technology transfer (information services, research and demonstration, and field services), it is the latter which is completely lacking in present Federal activities. DOC has the experience and, through EDA and the Office for Domestic and International Business (DIB), has many elements of the necessary field structure already in existence. Additionally, a new and vital mission for those field activities may serve to strengthen them.

[The following information was referred to on p. 164.]

INDUSTRIAL RESEARCH INSTITUTE, RESEARCH CORP.,
*St. Louis, Mo., November 30, 1979.*

To: Industrial Research Institute Representatives.
From: Hamilton Herman, I.R.I. Research Corp., Manager, Cooperative Technology Program Study.
Subject: Cooperative Technology Program Study for the U.S. Department of Commerce, Draft Report of 15 September 1979.

I am enclosing a copy of the draft report on Cooperative Technology which represents the end product of a study which the IRI Research Corporation undertook over the last nine months for the Commerce Department. The report covers consideration of the feasibility of Cooperative Technology Development efforts among Government, industry and the universities in nine technical sectors. The nine sectors were: Composite materials, corrosion, flexible automated manufacturing, organic coatings, powder metallurgy, radiation processing, semiconductors, textiles, welding and joining.

I will appreciate having your comments on the report and its contents. Please note the following disclaimer which applies to this report.

DISCLAIMER

This is an interim "draft" report. The content of this report does not represent official policy or conclusions of the Department of Commerce. The report should not be quoted or reproduced in whole or in part without including this disclaimer. For further information, please contact Frederick L. Haynes, Director, Office of Cooperative Technology, National Bureau of Standards (telephone (301)–921–2446).

COOPERATIVE TECHNOLOGY PROGRAM EVALUATION OF NINE CANDIDATE AREAS FOR INDUSTRY PARTICIPATION AND SUPPORT

THE INDUSTRIAL RESEARCH INSTITUTE RESEARCH CORP.

The Industrial Research Institute (IRI) is an association of approximately 250 companies that have joined together to exchange experience and to discuss ways and means of improving research and development operations as well as technology transfer and commercialization. Many of the leading companies with significant R&D operations belong to the IRI. The IRI has been asked from time to time to provide expert assistance to the government using its highly experienced membership (including retired members). It therefore set up the IRI Research Corporation (IRI/RC) to handle the contractual arrangements for such assistance.

The IRI/RC team which carried out this study was as follows: Dr. Howard K. Nason, President, IRI/RC; Mr. Hamilton Herman, Manager, Cooperative Technology Program Study; Dr. Leo S. Packer, Consultant.

*Sector teams*

*Automated batch manufacturing.*—Mr. H. Ford Dickie,* Dr. Gordon Vanderbrug (NBS), Mr. George P. Putnam, Prof. Wilbur Meier, Mr. Hamilton Herman, and Prof. George K. Hutchinson.

*Composite materials.*—Dr. Robert W. Cairns,* Dr. William A. Franta, and Prof. R. Byron Pipes.

*Welding and joining.*—Mr. Robert E. Somers,* Mr. David C. Martin, and Dr. Irving A. Oehler.

*Textiles.*—Dr. John K. Bragg,* and Mr. Joseph R. Martin.

*Powder metallurgy.*—Prof. Chester Spencer,* and Mr. Donald A. Gustafson.

*Organic coatings.*—Mr. Robert H. Baldwin,* Dr. John C. Weaver, Mr. Milton A. Glaser, and Mr. Leonard C. Afremow.

*Semiconductors.*—Dr. C. Lester Hogan,* Mr. M. B. Northrup, and Mr. R. E. Anslow.

*Radiation processing.*—Dr. John Kuranz,* Prof. Joseph Silverman, and Dr. William McLaughlin (NBS).

*Corrosion.*—Dr. Eric A. Walker.*

## I. INTRODUCTION

This study was carried out by the IRI Research Corporation under contract with the U.S. Department of Commerce.[1] The purpose of the study was to determine the feasibility and potential benefits of a Cooperative Technical Development Program involving industry, the government and academia and to identify appropriate development projects desired by industry.

Nine industrial sectors were surveyed through various mechanisms including personal visits to firms, universities and professional organizations, through telephone contacts, correspondence and available literature, through the expertise of the IRI/RC survey team assisted by personnel within the National Bureau of Standards and, finally, through a series of intensive one-day workshops. In all, the study contacted some 300 key industrial personnel, over 22 universities, 21 professional associations, 7 non-profit R&D institutions and 60 government employees associated with 8 major government groups.

The nine areas selected were: Automated batch manufacturing, composite materials, welding and joining, textiles, powder metallurgy, organic coatings, semiconductors, radiation processing, and corrosion.

It is noteworthy that linkages exist among the selected areas. For example, welding is actually an element of automated batch manufacturing, as are composites and powder metallurgy. Similarly, semiconductors are key factors in upgrading automated batch manufacturing, and industrial radiation processing can improve textile manufacturing as well as the drying of industrial paints and coatings. In many cases, it was found that projected benefits in one area would diffuse additional benefits to other areas.

To accomplish its objectives, the study would:

Determine for each sector whether there are significant technology needs and opportunities which are currently not receiving enough development effort and, which, if properly addressed, could materially strengthen industry and the nation;

Identify those opportunities which would be appropriate for government participation through a joint development effort with industry and academia;

Obtain from industry descriptions, including costs, of specific projects which would address the development needs;

Determine industry's interest in such a joint effort and identify Cooperative Technology Centers for undertaking the development effort;

Following the survey, organize for each sector a one-day workshop to discuss and evaluate the results of the survey, including the programs and projects. The workshop would also seek to obtain from the industrial participants a preliminary expression of industry's willingness to support projects with funding and other resources.

## II. EXECUTIVE SUMMARY

Industry by and large took the position that our nation would be far better off if government and industry worked together rather than operating with the substantial inefficiencies of the present adversary relationship. Many industry leaders are well aware of the declining competitiveness of U.S. industry in world markets, intensified by effective industry-government cooperation in other countries. Indus-

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* Prinicpal investigator.

[1] Contract No. NB-79-SBCA0039.

try therefore was willing to seriously consider proposals for more cooperative efforts between industry-government and academia and commended the Department of Commerce for its leadership efforts in this direction.

The study concluded that there are in the selected areas significant development needs which could benefit from increased development effort through a Cooperative Technology Program. These needs together with associated projects are described in the summary of each sector given in Section VI of this report and in more detail in the individual workshop proceedings available as Appendices. Recommended programs vary from increased use of computer aids in automation of batch manufacturing to development of technology for forming larger and more complex shapes through powder metallurgy, to research to achieve better understanding of physical phenomena of materials involved in semiconductor fabrication so as to permit increased circuit densities.

The accompanying chart gives for the first five years the estimated total operating expense and capital investment costs for each of the nine areas surveyed. These figures are based on estimates submitted for a selected group of recommended projects in each area. Depending on the rate of project buildup, the number of projects selected for implementation, and a more detailed analysis of project costs, the figures on the chart will vary by appreciable percentages. They indicate, however, the approximate magnitudes of funding required to mount a significant R&D effort in each area.

The potential benefits of the suggested developments vary from modest yields in the range of a few million dollars annually to others easily in the range of 20 to 30 billion dollars.

## OPERATING COSTS

[Millions of dollars]

| | Year— | | | | | Total 5 yr | 5 yr equipment and materials |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | | |
| Automated batch manufacturing | 1.0 | 9.0 | 10.0 | 10.0 | 10.0 | 40.0 | 25.0 |
| Composite materials | 1.1 | 2.0 | 2.1 | 2.5 | 3.0 | 10.7 | 3.0 |
| Welding and joining | .8 | 1.2 | 1.8 | 2.7 | 4.0 | 10.5 | 5.0 |
| Powder metallurgy | .7 | .9 | 1.5 | 2.5 | 2.5 | 8.1 | .8 |
| Organic coatings | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 15.0 | 4.0 |
| Textiles | 1.9 | 2.8 | 3.95 | 3.95 | 3.95 | 16.6 | 3.0 |
| Semiconductors | 4.0 | 10–15 | 27–34 | 27–34 | 27–34 | 95–121 | 10.0 |
| Radiation | .95 | 1.25 | .90 | .90 | .90 | 4.9 | 1.0 |
| Corrosion | 2.0 | 2.2 | 2.4 | 2.6 | 2.9 | 12.1 | 1.0 |
| Total | 15.5 | 32.4–37.4 | 52.7–59.7 | 55.2–62.2 | 57.3–64.3 | 213–239 | 52.8 |

Estimated total costs for significant cooperative technology programs.

In general, strong interest in a Cooperative Technology Program was expressed in six technical areas. Interest was limited in two—Textiles and Organic Coatings. In the Corrosion area, interest is unresolved. For further observations on industry attitudes, see the sector summaries in Section VI.

Industry's interest was conditional upon a number of critical elements. These are given in the General Discussion in Section IV. However, high on the list of critical elements were the following:

(*a*) Clear, comprehensive published statement of policies for the suggested Cooperative Technology Program together with details of the organizational structure and operating procedures. The operating system should be relatively simple and free of procedural red tape.

(*b*) Clarification of the antitrust restrictions as they would apply to the Cooperative Technology Program. This would require a policy definition from the Justice Department which would describe the limits within which industry could cooperate in the suggested development efforts. This is probably the most critical concern.

(*c*) A balanced program including not only development projects but also parallel emphasis on technology transfer, information handling and training.

(*d*) Funding levels compatible with the significant objectives together with continuity of support over a 5-to 10-year period.

(*e*) Solid support for the program at the top levels in DOC.

Industry repeatedly stressed the need for reduction of barriers to industrial inovation beside those arising from insufficient technology development. Industry is convinced that current taxation policies, excessive application or interpretation of environmental requirements and various "institutional" restrictions are the major obstacles to industrial innovation. It is pointed out that advanced competitor nations, especially Japan and Germany, in achieving greater productivity increases than the United States, operate with substantially lower barriers, expecially regarding cooperative development efforts and capital formation incentives.

Successful implementation of the Cooperative Technology Program now rests upon:

(*a*) Resolution of the critical program elements enumerated.

(*b*) Following this resolution, further dialogue with industry and further industry deliberation to provide more specifics on Cooperative Technology Programs and projects—leading to industry proposals to DOC.

(*c*) Legislative support from Congress.

*Recommendations*

The study yielded recommendations of two kinds: those relating to Cooperative Technology policy and those dealing with each of the nine industry sectors.

Regarding policy, the major recommendations were:

A clear, comprehensive and detailed statement of Cooperative Technology Program policies, organizational structure and operating procedures is needed as a next step.

Mutual confidence and understanding between DOC and industry at top levels are prerequisite to the program success.

The DOC needs to work toward reducing barriers to industrial innovation other than those arising from insufficient technological development.

Industry should be involved with each step in the development of Cooperative Technology Programs and should have a means for directly expressing its views and interests.

In addition to industry's primary input, there should be suggestions from other qualified sources such as the universities, professional societies, etc.

Cooperative Technology Programs should be coordinated with R&D plans and programs of other government agencies so as to obtain maximum effective potential from the total development funding.

A phased development program is recommended, starting with three or four significant projects.

In the nine technical areas, highlights of the recommendations are:

*Welding and joining.*—The Welding Research Council has submitted an initial phase R&D plan calling for projects on three major aspects of welding technology: welding materials, process development and control, and weldment design and performance. This approach is recommended.

*Automated batch manufacturing.*—Initial projects could be automation of arc welding, end effect devices for robots and larger and more complex shapes from powder metallurgy. Of great importance is an experimental batch manufacturing plant to develop, demonstrate and provide economic justification for more flexible, efficient batch manufacturing systems, including computer integration. Also recommended is a developmental retro-fitting capability for improving productivity of current manufacturing systems with minimum capital outlay.

*Semiconductors.*—The recommended program is this sector calls for projects in five critical technical areas, these projects to be undertaken at several university "Centers of Excellence."

*Powder metallurgy.*—The project on larger, more complex powder metal parts is recommended for implementation, using the Metal Powder Industry Federation as the coordinating entity.

*Composite materials.*—Industry's view is that currnet industry-university programs are working effectively but need more support in the form of equipment grants and funds for selected projects. Government assistance for existing centers is recommended at modest cost to stimulate industry cooperation, accelerate progress, and upgrade the magnitude and quality of ongoing projects.

*Radiation processing.*—Development projects at universities, with emphasis on training scientists and engineers, are favored by industry. Using this approach, initial projects recommended are concerned with electron-beam curing of thicker coatings and the use of gamma radiation for the preservation of certain foods, particularly bacon.

*Textiles.*—Although there is general agreement on the need for new technological developments, there is no industry consensus on priority projects or on a Cooperative Technology Program as the means to carry out the selected projects Dialogue

with interested representatives of the industry should be continued to permit later determination of the feasibility and desirability of a program on textiles.

*Organic coatings.*—The Scientific Committee of the National Protective Coatings Association is interested in the Cooperative Technology concept but requests about one year to consider possible projects and to determine industry's position on Cooperative Technology. A continuing dialogue is recommended.

*Corrosion.*—There is a strong consensus on the need for additional research on corrosion, but it was not clear that a Cooperative Technology Program was the best approach. Other ideas advanced were the expanded support of existing projects and centers, and a program largely financed by government with coordination and management by an existing government laboratory. The prospect for industry participation and support remains uncertain. A continuing dialogue is recommended to resolve this question.

## III. BASIC QUESTIONS AND METHODOLOGY USED

*Methodology.*—To accomplish the study, a group of expert consultants having substantial industrial and research experience was drawn together by the Industrial Research Institute Research Corporation (see Section VIIA). These experts, drawing on others, such as personnel at the National Bureau of Standards, trade and professional associations and university staffs, surveyed the selected industries as well as their suppliers and customers. The IRI/RC teams used the following methods: Personal visits to firms, universities, trade associations, etc.; telephone contacts; correspondence; analysis of available published information; expertise of the IRI/RC team members; and workshops.

*Basic survey questions.*—The basic questions used in the survey were:

(1) Industry's view:

(*a*) Are there technology development and utilization needs in this industry which, if satisfied, would materially strengthen the industry and which are not now getting the attention they deserve?

(*b*) Which of these, if any, could materially benefit from a cost-shared development effort between government and industry? Strengthen can mean: Improve productivity; improve product performance; improve profits; increase exports; reduce imports; reduce unemployment; and enhance worker health and safety.

(2) What programs and projects are suggested?

(3) What might these require in terms of money, manpower and facilities?

(4) What would their benefits be?

(5) Would the individual companies contribute funds and other resources to the "Cooperative Technology Center" and its projects?

(6) What is industry's view as to the management system for appraising, allocating and carrying out development effort?

*The workshops.*—The intent of the workshops, in addition to obtaining a consensus on the proposed projects, was to agree on estimates of benefits, money, manpower and facilities requirements, to discuss possible ways of selecting and structuring Cooperative Technology Centers, and to obtain industry's view of the management system proposed for the Cooperative Technology Program and the degree of interest in and commitment to the Cooperative Technology concept of individual firms. The results achieved for each sector are summarized in the following sections of this report.

## IV. GENERAL DISCUSSION, ISSUES, AND FINDINGS

### *a. Introduction*

Given the right financial, legal and operating support, the Cooperative Technology Program could make major contributions to industry and to our nation. The benefits would come not only through increased productivity but also through positive effects on international balance of payments, on smoothing employment dislocations arising from technology developments, on energy and resource conservation, and on those additional elements contributing to a sound, more productive national future.

It would also represent tangible progress in reversing the general decline of industrial innovation perceived in this country in the last decade and a step forward in industry-government relations which is an indispensable element in Cooperative Technology.

Industry in general agrees that we are losing ground in comparison with our overseas competitors, that there is a genuine need for industry, government and the universities to work together in the national interest and that industry is willing to discuss how cooperation might be achieved.

*b. Industry characteristics and concerns*

*Nonhomogeneity.*—Industry, including its various segments, is not homogeneous. Therefore, the response to any proposal such as the Cooperative Technology Program consists of a spectrum of views with variation among industries as well as among companies within an industry.

*Competition vs. cooperation.*—Since industry operates in a competitive marketplace it is more accustomed to competition than to cooperation. Further, the antitrust laws assure that companies in a given industry will carefully avoid working together.

*Unaccustomed to working with the Government.*—Many of the industrial companies approached in the Cooperative Technology survey were not companies habitually doing business with the government or dependent on government contracts for their success. These companies are therefore not accustomed to government contracting procedures which are considerably more complex and time-consuming than those in general industry. Whatever modest experience these companies have had with the government has led them to be cautious about getting involved with the government, expecting to encounter excessive "red tape," time delays and a host of "boiler plate" operating requirements. In their view, innovative development work is difficult in itself and cannot operate effectively in an atmosphere of red tape and special imposed operating conditions which do not promote the quality of the effort—a critical element in innovation.

*Drift away from the universities.*—Industry has tended in general to drift away from the universities as the universities have reduced emphasis on practical applications such as more immediately useful education (i.e. manfacturing technology) and have tended to take a position viewed by many in industry as being cool to the private sector. At the same time, in technology the universities have found that they could often obtain research funds from the Federal Government which were of more dependable continuity than funds from industry. Therefore, the universities did not have to be concerned with industry needs.

*Government-industry hostility.*—The rapid growth of Federal Government regulatory agencies, especially the Environmental Protection Agency and the Occupational Safety and Health Administration, together with numerous cases of excesses in regulatory actions have created a hostile feeling toward government in many areas of industry. The antipathy seems to be stronger in the medium and smaller companies which, in contrast to the large companies, are generally less able to afford the burdens of paperwork, legal expenses and operational changes brought on by the regulations. The hostility created by what are viewed as excessive regulatory demands builds on resentment arising from taxes and antitrust problems. Industry sees the current tax and regulatory situation as diverting capital and operating funds necessary for healthy growth (including innovation) and creating substantial operating inefficiencies which directly reduce productivity.

*Contrast with our overseas competitors.*—Industry sees the results of the tax, antitrust and regulatory problems to be a direct reduction in our ability to compete with leading overseas nations. In contrast to the United States, our principal competitors have industrial development policies which encourage capital formation and promote cooperate among industrial firms and between government and industry in a doctrine aimed at promoting the best interests of their countries within the international community.

*Obstacles to the cooperative technology program.*—The non-homogeneous nature of industry, its competitive traditions, and its antipathy toward the Federal Government present appreciable obstacles to the cooperative premises of the DOC program. This is true despite the statement that Cooperative Technology concerns itself only with technical development. It is industry's view that technical developments are meaningless unless the capital and operating funds necessary to pursue the developments are available. This is particularly true since the cost of commercializing a technical development can run from 10 to 50 times the cost of the R&D.

*Possibilities and elements for cooperation.*—Despite these very real hurdles in the path of a Cooperative Technology Program, there are many companies which believe that it would be far better for the nation if industry, government and academia worked together instead of under the present adversary relationship. Among these companies there are quite a few who hope that the DOC effort toward cooperation would succeed. They are willing to join with DOC in working toward this end, even if the odds of success are less than even. However, they tend to believe strongly that such efforts would not be successful unless:

1. Industry can choose, design and manage projects with minimum government red tape, administrative procedures and bureaucratic burdens.

2. They are given credible prior assurance that they will have freedom from unreasonable antitrust restraints within the Cooperative Technology Program.
3. The program does not involve "yet another" sizeable corollary government bureaucracy.
4. Continuity of government support is assured for an adequate period of time (up to five years) to help carry a cooperative center toward adequate self-sufficiency.
5. Funding is adequate to support a truly significant level of development effort. Such funding can vary from something on the order of $1 million to tens of millions depending on the program area.
6. The Secretary and other key officials of DOC are able to convince industry that they firmly believe in the value of the program, will so assure key industrial leaders and will strongly promote the Program with the White House and Congress.
7. Industry will have a strong voice in how the program is structured, organized and operated.
8. Provision is made to minimize politicizing forces. Insofar as possible, objectivity should be built into the procedures for selecting management, advisory personnel and cooperating institutions.
9. The Program is designed to emphasize non-proprietary R&D.
10. Companies providing funds for the Program should have preferential access to the results over nonparticipating firms, including policies in respect to publications and documentation.
11. Existing qualified nuclei for cooperative centers are used in preference to new centers.
12. Existing trade associations and professional societies that represent an industry or a technology are used for guidance.
13. Existing cooperative relationships should be considered complementary to a Cooperative Technology Program. These relationships can exist among industry, government, universities, trade associations, consultants and private laboratories.
14. A satisfactory solution can be found to the problem of early diffusion of R&D results to overseas competitors and noncontributing companies.

*c. Industry obligations in a cooperative technology program*

A cooperative program implies contributions by each of the parties involved. If the Federal Government can meet the role set forth by the program targets as well as the concerns of industry, then both can agree that industry for its part has particular obligations to the joint effort. Essentially, these would be:

1. Industry should provide senior management support for the Program.
2. Industry should enter the program with the serious intent to make the program successful.
3. Industry should put forth projects of substantial potential benefit which it would not otherwise do on its own or which it could not do at the most desirable rate.
4. Industry should contribute resources of its own to the projects. These could be manpower, equipment and capital and operating funds.
5. Industry should enter the partnership with the firm intent to provide continuity of development effort over the minimum expected period of 5 to 10 years.
6. Industry should strive to develop financial self-sufficiency in Cooperative Technology Centers so that the government's role is progressively reduced as the Cooperative Technology Centers acquire technical strength and a track record of accomplishments.
7. Participating industrial firms should be alert to opportunities to exploit the results of the Cooperative Technology Program by undertaking proprietary R&D that builds on a growing base of generic technology.

*d. Program returns*

The stated objective of the Cooperative Technology Program is to increase industrial innovation, thereby strengthening industry and the nation, especially in terms of productivity, international competition, inflation, unemployment and product performance. A number of qualified studies have shown that technology development is a major contributing factor (40–60 percent) to increased productivity. This study rests upon that premise.

In the fields of basic research and generic or "underlying" technology, economic paybacks can be shown to be very great but can usually be quantified only over extended periods of time, usually decades. The generic technology projects described in this study, such as the project concerned with the curing process in composite materials, fall in this category. Nevertheless, economic benefits can sometimes be inferred from comparison with successful similar efforts in the same technology area and sometimes from certain specific elements within a project. In this way the

study has attempted to estimate tangible economic benefits whenever possible. Thus, in the manufacturing area the study shows the dollar extent of manufacturing value-added which would be impacted by new technology in computer-aided automated batch manufacturing. Using improvement percenages which have been demonstrated in successful automation of batch manufacturing operations to date, the estimated economic potential benefit of further automation of batch manufacturing operations was made. The potential benefit was substantial—in the range of $15 billion. Likewise, specific cases of robot applications have shown 50 percent improvement in productivity. Powder metallurgy potentials were conservatively estimated on the basis of increased applications in the automotive industry, rather than trying to estimate benefits throughout all metal fabricating industry.

Certainly one of the most important benefits from the program would be the attainment of greatly improved government-industry-academia dialogue and cooperation. An additional gain would be the stimulation of greater innovative effort by industry itself.

The information obtained thus far does indicate very substantial potential benefits from a successful Cooperative Technology Program. Ongoing dialogue with industry, including more specific description and analysis of projects, will further provide tangible support for this conclusion.

*e. Project and industry variations*

The study revealed a wide diversity in type and scope of projects proposed for consideration and in industry attitudes toward R&D and the Cooperative Technology concept.

In certain sectors of high technology, R&D is a primary and indispensable factor in the health and survival of the indusry. In other industry areas, R&D is given less importance compared with regulatory and environmenal costs, worker health and safety, capital availability, taxation, import competition, etc.

In some cases, proposed projects represented a "laundry list" of technical themes for the industrial sector. Some participants favored extension and accelerations of existing R&D programs; others favored emphasis on substantial new directions. Some suggested the need for better understanding of basic physical and chemical processes underlying a technology area while others favored development efforts directed more toward applied technology. A major common theme in almost all programs was the need for non-R&D activities to go hand-in-hand with the development projects in a Cooperative Technology effort. These activities include documentation and information dissemination, training and education, demonstration projects, consulting services, and preparation of design guides.

There were marked differences between the newer, high-technology companies and those engaged in older technologies.

A small number of participants stated satisfaction with the current status of R&D in their industry and their companies.

Industry attitudes and reactions varied not only between industrial sectors but also within each sector. While they varied with company size within a sector they even varied with companies of the same size.

These variations suggest the need for considerable flexibility in the Cooperative Technology Program. In some cases they also suggest the need for further analysis and dialogue in order to make sure that projects proposed for the Program meet criteria for significance and justify government participation.

*f. Funding considerations*

In respect to funding there was general agreement by industry on the following elements:

(*a*) Government seed money would be a valuable stimulus in getting Cooperative Technology Programs on their way.

(*b*) Most industrial contacts believed that a split in funding which started with 80–20, a government-industry, and developed in the direction of 20–80, government-industry, was the best arrangement for initiating the programs.

(*c*) Within the Cooperative Technology Centers a substantial portion of the funds should be devoted to the areas of technology transfer, demonstration and training. Industry understands the Department's interest in directing its support primarily to development efforts, but consistently points out that the other areas are critical to the implementation of the developments. It is quite likely that industry would be willing to carry the major portion of these implementation expenses.

(*d*) Within a given sector it is considered likely that certain projects will be supported by particular groups of companies rather than by all companies in the program. For example, equipment manufacturers may well seek to concentrate

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their support in equipment development rather than in development of new or modified materials.

(*e*) Smaller companies tend to specify that their contributions go toward training, demonstrations and information transfer. The medium sized companies support these activities but also support applied research having near and mid-term potential. The large companies, while also agreeing on the technology transfer functions, tend to support longer range, higher risk research efforts which they see as augmenting their own mid-range efforts.

*g. Mechanisms*

A large number of variants of Cooperative Technology Program mechanisms were suggested and discussed during the study. It was clear that each area was unique and required a specific mechanism to fit its requirements.

For semiconductors, a major national development laboratory was suggested for consideration along with a small network of existing university centers already having recognized expertise in this area. The use of the Semiconductor Industry Association (SIA) to assist in planning and coordinating the development activities was also suggested.

In powder metallurgy, the Metal Powder Industry Federation is setting up a non-profit corporation similar to the DOC concept for a Cooperative Technology Center. The Federation via its non-profit corporation could function as an industry-wide coordinating mechanism to manage the Cooperative Technology Program.

In the composites area, the consensus was that existing industry-university relations should not be disturbed; that the existing centers should be reinforced with equipment grants, without attempting to set up new Cooperative Technology structures and organizations.

The Welding Research Council and the American Welding Society are well established in the welding community and can provide within their membership and committees the people to analyze, propose and manage projects. They have established development relationships with qualified universities. Both organizations have formally approved the Cooperative Technology concept and are developing more detailed project plans in anticipation of possible activation of the Cooperative Technology Program.

The coatings industry through its trade organization, the National Protective Coatings Association, currently sponsors a modest number of R&D projects on a cooperative basis. Its members suggest that this organization should manage a Cooperative Technology Program. It is possible, in addition, that a consortium of firms might wish to set up special programs.

For the areas of manufacturing and radiation processing it is not clear that suitable mechanisms or institutions exist which could be used as a nucleus for a Cooperative Technology Program. Additional consultation within each industry will be required to evaluate what exists and to determine what needs to be created in each case.

In the corrosion area there were suggestions that Cooperative Technology efforts beyond those already in effect between universities non-profit technical institutions and industry might need to be funded primarily by the Federal Government with overall management and coordination of development work thus funded to be provided by an existing government laboratory such as the National Bureau of Standards. Under such an arrangement, the development effort would be outside of the DOC Cooperative Technology Program as presently conceived.

The above brief examples illustrate the need to consider each area as a special case, to discuss each situation with the industry and research leaders, and to design each new mechanism so as not to disrupt or compete with existing arrangements, especially if they are working effectively.

*h. Extent and limitations of the study*

Each survey team was composed of senior personnel having very extensive industrial experience in that area. In special cases the team also included key research personnel from the universities, further assisted by experts within the National Bureau of Standards. The teams covered industrial firms, trade and professional organizations, universities, non-profit R&D laboratories and pertinent government development groups. In all, the study contacted some 300 key industrial personnel, over 22 universities, 21 professional associations, 7 non-profit R&D institutions and 60 government employees associated with 8 major government groups.

The coverage was selected to provide balanced and meaningful perspective on the development potentials in each area. It must be recognized, however, that from a statistical viewpoint the coverage is quite small and therefore necessarily subject to a fair degree of uncertainty. Further, the survey was carried out in a relatively

short length of time—essentially four months—followed in each case by a one-day workshop. Should more time and funds become available, it would be constructive to extend the survey, especially covering a wider distribution of industrial firms, not only in numbers but also in terms of size and status within the industry.

Based on the experience of the study team, the selected coverage, and the general absence of wide divergence in the workshops, the results of the survey are believed to be close to those which would have been derived from more comprehensive sampling. As described above, the primary uncertainties are concerned with extent of industry coverage and the shortness of time for industry to think through its position on the Program.

## V. RECOMMENDATIONS

*1. Completion of comprehensive statement of policies for the cooperative technology program together with the details of the organizational structure and operative procedures*

The survey of the industrial areas has been carried out using a variety of information sources on the Program such as the interim report of February, 1979,[1] various presentations by Department of Commerce and National Bureau of Standards personnel, the brochure entitled "Cooperative Technology Program" prepared by DOC and the brief statements prepared by the Industrial Research Institute Research Corporation. Considerable industry and university interest in the Program has been generated by the numerous meetings, surveys and workshops.

The Program suggestions by DOC together with their consideration by industry and the universities have now provided a reasonable basis for firming up the details of the Program. Interest has reached the point where further progress rests to a considerable degree on adequate description of those details. Industry's concern with the need to clarify the details is given in the General Discussion section of this report. The statement of detailed Program policies, organization plans and operating procedures would cover, for example:

The DOC Cooperative Technology Program organization (diagrams, size, functions).

The composition of the Policy Committee; how to insure that its advice is accepted; how to insure its high quality and continuity; how to provide access to policy and decision makers in DOC.

The operating system: procedures for obtaining funds, for accounting for funds; reviews and reports required, etc. Note: those members of industry who have seen the interim report consider the approval procedures described there to be much too cumbersome and complex.

Clarification of the antitrust situation including a statement which adequately describes the boundaries within which industry can engage in cooperative effort.

Policy providing for variation in the "Cooperative Technology Centers" consistent with the different existing structures, technical status and requirements of different industrial sectors.

Government policy in response to repeatedly expressed concerns of industry in respect to the Cooperative Program (see General Discussion), i.e., procedural red tape, bureaucratic size, protection of intellectual property, etc.

Government expectations regarding industry obligations (see again, "General Discussion").

Policy on program balance in the development effort, including technology transfer, information handling, and training. The technical development effort will be of little use if it is not pursued to commercial application. It is in this area where the Japanese have now surpassed the United States. If the Cooperative Technology Program is to succeed in the real world, it must include concrete provision for the optimum transfer and application of the results of development projects.

Policy on size of programs and projects. The current non-governmental R&D expenditures approximate $30 billion annually. The R&D budget for several of the larger industrial companies individually is over $500 million per year. A Federal development program aimed at having a significant national impact must contemplate expenditures in excess of a few millions or even a few tens of millions of dollars. This is not to say, however, that significant start-up programs cannot be carried out with the lower figure. Policy would need to recognize the ultimate funding reality while starting modestly to gain operation expertise and prove program validity. The point is not to promise too much from too little and thus lead later to collapse of support when program yield falls short of expectations.

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[1] Office of Science and Technology, U.S. Department of Commerce.

The Cooperative Program proposal is motivated by a desire to marshall U.S. technical resources in order to maintain a strong U.S. competitive position in the face of well funded and skillfully organized foreign cooperative efforts.

Success will depend on the assurance of a sustained commitment by the U.S. Government and industry partners, and on the assurance of funding levels consistent with the magnitude of the overseas challenge. In particularly critical areas such as semiconductor fabrication, for example, or automated batch manufacturing, the U.S. effort will have to be at a level to match the substantial individual foreign national investments (e.g. Germany or Japan).

The necessity to provide adequate funding in each selected area suggests that the Cooperative Program should concentrate on a limited number of projects of major potential rather than to dilute its funds through numerous projects of modest or small potential.

Government policy to provide substantial seed money can assure industry that Government is serious about the program. Further, the seed money can do much to overcome natural start-up barriers.

Operating structure and mechanism should take into account the favorable features seen in the cooperative programs of overseas competitor nations but adapt them to our own system and special capabilities.

*2. Need for substantive cooperation between industry and government*

It is recommended that close ongoing communication and liaison be provided for. Good communications is certainly a fundamental of a sound partnership. It is suggested that one mechanism to promote this objective would be to have resident senior industry liaison personnel "on loan" to DOC, and to give them both adequate "position" and a voice in decision making.

*3. Toward mutual confidence*

Cooperation will ultimately depend on mutual confidence. This in turn will rest on understanding at the top management levels, for that is where the policy, financial and critical operating decisions are made.

To date the IRI Research Corporation survey has covered primarily key R&D managers in the various industrial sectors. A number of senior general managers were also contacted. However, for the most part the general managers first wanted their R&D managers to address the development needs and the program proposals. After that they would evaluate the specifics of projects proposed and take a careful look at the details of DOC policies, organization and operating procedures for the program.

Progress resulting from the survey and discussions has reached the point where a mutual agreement on the value of the program and how it will work should be reached between the Secretary of Commerce and the chief executive officers in those industrial sectors proposed for joint development programs with the government. From this meeting both parties must emerge with the conviction that the other party will make a serious effort to assure that the Cooperative Technology Program comes about and has suitable policies and procedures. It is apparent from the IRI/RC survey that industry needs reassurance that the Commerce Department is committed to the program and will support it vigorously with the White House, OMB, Congress, FTC and the Justice Department.

*4. Need for vigorous effort on the part of DOC for reduction of other barriers to industrial innovation*

Large elements of industry are convinced that current taxation policies, overly zealous application or interpretation of environmental and safety and health requirements and various "institutional" restrictions are the major barriers to industrial innovation. This opinion is highlighted by examination of more favorable policies in competitor nations. For example, in the matter of taxes, semiconductor industry spokesmen point out that to obtain the maximum in Incentive Tax Credits, industry is required to write off qualifying equipment over a 10-year period. However, in its dynamic technical environment, such equipment is usually obsolete in no more then three or four years. The Incentive Tax Credit thus does not function effectively in the semi-conductor industry. Coatings industry people say they are caught in the "no-win" situation where they are required to cease using certain key present technologies but have not been able to penetrate the red tape to obtain government acceptance of suitable alternate technology. The textile industry points out that meeting current government regulations can absorb all of its cash over the next few years, leaving little for any form of innovative growth.

Industry would like to see DOC provide a continuing strong push for reduction of these other real barriers to innovation. In industry's opinion these are far more

serious than shortages of R&D efforts and their reduction would provide substantial immediate benefits.

*5. Industry must speak for itself*

The Commerce Department wisely set out to solicit industry's views on the Cooperative Technology Program. In ongoing dialogues this consultative approach should be maintained. Whereas the universities, government technical observers, and others, can and should provide useful inputs to the Cooperative Program, they cannot speak for industry itself. If the programs are to be accepted by industry its voice must be heard directly, not through interpreters. Otherwise it is most likely that projects would not find full acceptance in industry. A problem in this respect arises because certain industrial sectors do not have a suitable mechanism for focusing the discussions. This is not true in welding, where the Welding Research Council and the American Welding Society both can serve this function; in the powder metallurgy sector, where the Metal Powder Industry Federation has been organized, or in the semiconductor area where the Semiconductor Industry Association and the Semiconductor Equipment Manufacturers Industry already operate. However, in other areas, pending organization of an industry focal point, a temporary focal point for the members might be necessary. Such a temporary focus could be the IRI Reserach Corporation or another organization with strong industrial ties. For example, there is no "radiation processing" association nor is there an appropriate one with general manufacturing unless a special one is set up within an organization such as the Society of Manufacturing Engineers.

*6. Need for balanced program input*

The preceding section mentioned the need for program selection input by the universities, government observers and nonprofit laboratories. Current policy has been to seek similar input also from large, medium and small industrial companies, from manufacturers and users, and from both R&D managers and top general managers. This balanced input should be continued.

*7. Coordination with other Government agencies*

It is evident that the Cooperative Technology Program can gain by coordinating its development plans with other appropriate government development operations such as those in DOD, NASA, NSF, DOE, etc. Substantial increase in effective strength can be had in this way. To realize the potential one need only look at semiconductor programs in DOD, basic research in NSF (in almost all areas thus far considered for CTP), advanced composites development in NASA, the computer-aided manufacturing program in the Air Force, etc.

Beyond these groups there are the environmental agencies, EPA and OSHA, which have an impact on innovation. The Department of Commerce should play a substantial role toward reducing innovation problems arising from operations of these agencies.

*8. Development phasing*

It is recommended that the program plan provide for a phased development. Thus, the program would start with three or four significant projects and build from there. This will provide the necessary time for organization building, for learning, etc. Such a plan could call for starting in the manufacturing area where there is potential for very large payoffs. Thus, initial projects could well be: (*a*) Planning and initial organization stage for a developmental automated flexible batch manufacturing plant. (*b*) Automation of arc welding. (*c*) End effect devices for robots. (*d*) Larger and more complex powder metal shapes.

Analysis, dialogue and planning for additional projects, especially in the semiconductor area, can continue while these projects get under way.

*9. Projects*

Keeping in mind the requirements for Cooperative Technology Program projects and the results of the IRI/RC study, the following recommendations are submitted in respect to the nine areas covered in this study:

*Welding.*— Industry through the Welding Research Council and the American Welding Society has expressed a strong interest in the Cooperative Technology Program and has developed project descriptions in addition to plans for university centers. Welding is very pervasive in industrial manufacturing and yet is not an industry in itself. IRI/RC considers this a proper area for Cooperative Technology.

The Welding Research Council has very recently submitted an initial phase R&D plan which the Council worked out with three universities. The plan calls for interdisciplinary research projects focused on three major aspects of welding technology: Materials for Welding, Process Development and Control, and Weldment

Design and Performance. The projects can provide high economic benefits, especially through conservation of materials and increased productivity in batch manufacturing. The project on significance of weld defects to service performance has the potential, along with improved inspection methods, of reducing repair costs on the proposed Alaskan gas pipeline by many millios of dollars.

It is recommended that the projects for welding of thick section (especially pressure vessels) be further detailed in respect to potential economic benefits, including those in the energy area. Additional welding projects for the Cooperative Technology Program have been suggested. It is recommended that these be further examined for later inclusion in the program. It is also suggested that deeper examination of potential new welding technology (i.e., laser welding, E-Beam welding) be made for possible Cooperative Technology.

*Automated batch manufacturing.*—Place high priority in this area which can directly impact 30 to 50 billion dollars of value added in metal fabrication. Within this area initial projects can be automation of welding processes, larger and more complex shapes from powder metallurgy and end effect devices and adaptive controls for robots. Each of these projects will fit into the automated batch manufacturing area and each has substantial prospects for industrial sponsorship in Cooperative Technology. The first two projects are sponsored also in the sections on welding and powder metallurgy.

Very high priority is recommended for the developmental batch manufacturing plant for it is the development and utilization of more flexible, efficient batch manufacturing systems (including computer integration) which can have a profound beneficial effect on a very large number of our large, medium and smaller manufacturers. This project is currently in "skeletal" form, has been highly recommended by several most qualified manufacturers, and is being refined with the assistance of interested firms. Its scope is such that its ultimate, detailed specification will require further work including "mini-workshops" with interested companies.

Within the same development facility is projected a developmental "retro fitting" capability to examine and develop the technology for achieving appreciable (i.e., 30% +) improvement in the productivity of current manufacturing systems. Success in this area could have very great benefits to medium and smaller manufacturers (and the nation) through increased productivity with minimum capital outlay.

*Semiconductors.*—This is an area with a large and pervasive impact on the national economy. In view of this, and considering the substantial subsidized attack from overseas, it is most important that the U.S. put together a strengthened program to provide better understanding of the technical underpinnings of the industry. The semiconductor industry is aware of this and is actively considering possible cooperative efforts.

Because of the many disciplines and the magnitude of the effort called for, a real question concerns the basic approach to a cooperative program. A number of representatives from the industry feel that there should be a limited number of universities performing the development work. In turn, these would train graduate engineers for an industry that is in continual short supply of technical people. There is also a qualified opinion which feels that the magnitude and importance of the development task calls for a "national effort" through a major central development laboratory (similar to the Lincoln Laboratory or Jet Propulsion Laboratory but with more industrial oversight).

Consideration of this question concerning Cooperative Technology Centers, in addition to further project evaluation and detailing, more clarification of antitrust considerations (because of the various elements of the industry) and further discussion of the issue by industry management signifies that this program area will require more time for resolution. A target of December 31, 1979, for final resolution is reasonable.

Total project funding should be in the range of $4 million in the first year, to about $30 million in the third year and the industry assumes it may contribute 50 percent.

Although the project list and final recommendations from the industry are not complete, Semiconductors remains an area of critical import.

*Powder metallurgy.*—The powder metallurgy industry is composed of a group of relatively small companies and a few large operations which are divisions of large corporations. Substantial economic benefits can be realized through the development of effective means for making large (greater than 5 pounds) and more complex shapes. Additionally, there are needs to develop automated manufacturing processes for powder metal parts and to accurately determine the properties of powder metallurgy materials.

The Metal Powder Industry Federation, partly as a result of its dialogue in respect to Cooperative Technology, is proceeding to set up a nonprofit research corporation. This corporation will be authorized to develop cooperative developments with the government when the policies and operating procedures for the Cooperative Technology Program are fully spelled out. It is recommended initially that the project on large and more complex shapes be considered favorably for the Cooperative Program.

*Composites.*—The industrial companies with whom the composites area was discussed pointed out that they already had Cooperative Technology Programs going with various universities. Their opinion seemed to be that in their area the need was for more support in the form of equipment grants to existing centers. They further felt that there was no need for any new "Cooperative Technology" organization. It is recommended that sponsorship of centers in this area for the Cooperative Technology Program be undertaken as a low cost experiment to determine whether modest government grants can indeed stimulate the growth of industrial cooperation and support and the establishment of new, effective centers.

*Radiation.*—Radiation processing of coatings justifies support on the basis of energy and cost savings, especially for thicker and opague films. For thin films ultra-violet processing is usually more economical. The project for stack gas treatment could have major impact in the energy industry. It is felt that further appraisal of prospects for this method needs to be made in respect to prospects for developing reduced costs and for its position in respect to Japanese patents. The project on food sterilization obviously has very large potential economic impact. However, this project would need special consideration since it calls for advocacy with the FDA in respect to acceptance by FDA of radiation processing of certain additional foods (i.e., strawberries). IRI/RC would like to see more description of suggested food sterilization developments by radiation processing, beyond the extensive work undertaken to date by the government at Natick. As is the case in several other industrial sectors, industry emphasizes the need for more scientists and engineers and therefore is in favor of development programs at universities since such programs could help fill this need.

*Textiles.*—There are clear benefits of new technology for this industry, but there is broad diversity of opinion among industry R&D people on the wisdom of achieving these through a Cooperative Technology Program. Current study efforts are detailing several of the projects which appear to have the greatest impact and have appealed to those in favor of a possible Cooperative Program. These projects will then be reevaluated for validity in the Cooperative Program and for interest by industry. This industry, in common with certain other, also wishes to withhold opinion until the policy, organization and operating procedures are clarified as given in recommendation #1. The recommendation of this study in this area is to continue the dialogue with the interested members of the industry and to develop specific and detailed program plans for high priority projects.

*Coatings.*—Industry via the National Protective Coatings Association Scientific Committee is interested in pursuing a possible Cooperative Technology Program. The Committee suggests time (one year) to decide industry postition on Cooperative Technology, including projects. Projects being considered have substantial impact on the industry and its productivity, especially those projects concerning process developments which can offer solutions to the serious problems brought on by the many new regulations. Continuing dialogue with this group is recommended.

*Corrosion.*—It is recommended that the corrosion area be given further study in order to more clearly indicate the most desirable route to increased development efforts. The survey showed agreement on the need for such increased development but a difference of opinion as to whether this should be achieved through a government-industry shared cost program such as that proposed by DOC, through expanded support of current efforts and centers or through a program financed almost entirely by the Federal Government with program management by an existing government laboratory. One of the principal unresolved questions is the degree to which industry would contribute to a longer range, non-proprietary research effort in this area.

## VI. SUMMARIES OF EACH INDUSTRIAL AREA

### *Automated batch manufacturing*

*Summary*

Manufacturing constitutes over two-thirds of the total wealth-producing activity in the United States. Reduction in the cost of manufacturing can therefore have a

major beneficial effect on the economic well-being of the country, including its competitiveness in world markets.

Within the manufacturing area it is estimated that in 1979 manufacturing value added came to approximately $300 billion in the five metal fabricating areas. That portion which would be directly impacted by development and application of new technology in computer integrated flexible batch manfacturing systems is probably in the range of $30 to $50 billion. Cost reduction targets of 30 to 50 percent are considered achievable. Such reductions then can represent a major target toward offsetting inflation. A Cooperative Technology Program in automated batch manufacturing would contribute directly to this target. It is in this area where lagging growth in U.S productivity has led to the reduced international competitiveness of American industry. For the first time the U.S. Machine Tool Industry showed in 1978 a trade deficit: Metal cutting and forming tools—1978 exports, $715 million; 1978 imports, $765 million.

The United States faces more so than ever before in its history major competition in manufactured goods from its international competitors. Determined to increase their own economies, especially through increased development of overseas markets, our international competitors have put together substantial programs to improve manufacturing productivity. These programs generally place major emphasis on cooperative developments by government, industry and the universities—a consolidated national effort quite in strong contrast to the adversary relationship between government and industry currently in effect in the United States. These overseas cooperative development efforts are especially strong in Japan, Germany, Norway, Netherlands, the United Kingdom, Comecon countries, and the USSR.

Their efforts stress: (1) Integrated manufacturing software systems; (2) Group technology and cellular manufacturing; (3) Computer controls; (4) Multi-station flexible manufacturing systems; and (5) Computer-integrated automated factories.

*Reaction to cooperative technology program*

The preceding discussion indicates that there are significant development needs in U.S. manufacturing and that these needs are substantial in the area of batch manufacturing. They encompass interlocking elements of the entire batch manufacturing system under the overall heading of computer-aided manufacturing.

These developments are particularly appropriate to joint development effort because they spread over both a wide range of technologies and wide range of industry segments. It would be extremely difficult, if not impossible for one industry segment, such as the machine tool industry, to solve the main development problems involved.

While industrial firms interviewed had certain reservations in regard to a cooperative technology program and a few companies were outright opposed to any such relationship with the government, the general opinion was favorable provided potential problems could be overcome. Thus, during the workshop on automated batch manufacturing, eighty-one percent of the firms attending wished to continue the dialogue toward developing a Cooperative Technology Program.

*Prospects for cooperative technology program (CTP)*

The potential benefits of such a program are of major national magnitude. They would be especially valuable to medium and smaller manufacturers who most need the efficiency increases which can be had from the new technologies such as the use of mini-computers in manufacturing operations. The increase in manufacturing efficiency which can easily reach thirty percent, and in some cases substantially more, will be of real benefit in offsetting costs reducing inflationary forces and improving international competitiveness and thus our balance of trade. In directly impacting $30–$50 billion of value-add manufacturing in the metal fabrication area of approximately $300 billion, it is readily apparent that even modest cost reductions will provide multi-billion dollar benefits.

The automated batch manfacturing study was directed at three specific areas: Robotics, Flexible Manufacturing and Computer Integrated Manufacturing. The specific R&D projects recommended for these areas during the study were:

*1. Robotics.*—Arc welding; robot safety; force and torque sensors; machining/inspection; position accuracy; overhead conveyors; end effector; machine vision; part modeling data base; assembly; programming language; and non-rigid material handling.

*2. Flexible manufacturing systems.*—Technology transfer and innovation; system justification methodology; and planning tools.

*3. Computer integrated manufacturing.*—Microprocessor software for sequencing logic; software for three dimensional design; automated products testing; automatic parts inspection; and computerized system for machine scheduling and loading.

A Computer Integrated Flexible Batch Manufacturing System not only encompasses all of the elements given above but more significantly addresses the most basic current development need of our manufacturing area. Therefore, a major project proposal has been initiated to address this need. It involves setting up a developmental computer integrated flexible batch manufacturing plant. This plant would provide the base for developing, integrating and proving out the elements of such a plant and would then provide demonstration of the economic and operational advantages of such a plant (including the practical boundaries for these). Associated with the production functions of the plant would be the other key elements of the developments: manufacturing information systems, research and development and technology service and transfer.

This project can have substantial value to large, medium and small manufacturers. The largest manufacturers have a substantial amount of job shop production to provide replacement parts. Many large companies also have original products produced in smaller quantities (i.e. steam turbines). A substantial portion of the production of medium and smaller companies is in modest volumes where transfer lines are not profitable. Therefore, this project appeals to the full range of manufacturers and gains the support of the largest, most capable manufacturers. Timing would appear to be excellent. Computer integrated manufacturing has arrived together with mini-computer, robot and microprocessors at reasonable costs.

FUNDING ESTIMATES

[In millions of dollars]

| | Capital investment | R. & D. expense | Personnel and overhead | Total operating expense | Total man-hours |
|---|---|---|---|---|---|
| 1st year | 0 | 0 | 1.0 | 1.0 | 10 |
| 2d year | 5.0 | 5.0 | 4.0 | 9.0 | 40 |
| 3d year | 7.5 | 5.0 | 5.0 | 10.0 | 50 |
| 4th year | 7.5 | 5.0 | 5.0 | 10.0 | 50 |
| 5th year | 5.0 | 5.0 | 5.0 | 10.0 | 50 |
| Total | 25.0 | 20.0 | 20.0 | 40.0 | |

*Participants.*—Industry 56; Non-profit foundations 3; Universities 13; Government (including NBS) 10; National Science Foundation 3; National Machine Tool Builders Association; National Tool and Die Association; Robotics Institute of America; National Academy of Sciences; Society of Manufacturing Engineers; and IRI/RC.

*Composite materials*

*Summary*

*The industry*

Composites represents about $5 billion per year of revenues, with a current growth rate of 10–15% per year. During the past 30 years, the industry grew more slowly, depending largely on empirical methods to develop materials, processes and applications. Recently, with growing economic incentives to use composites for energy conservation, weight reduction, corrosion and fatigue resistance, and noise reduction, the industry has been stimulated to faster growth, with new requirements to improve basic technology and develop new applications. It has been estimated that one percent of additional growth rate is worth about $50 million in expanded business.

The industry consists of a large number of materials suppliers and fabricators, ranging from small custom shops to large captive operations in multibillion dollar corporations. Different classes of applications have widely different manufacturing methods and technology needs—aerospace, automotive, applicances, boats, construction, etc.

Active research centers exist at MIT, Texas A&M, RPI, Stevens Institute of Technology, University of Delaware and University of Tennessee. NASA and the U.S. Air Force are supporting significant applied R&D. The industry-university relationship is well established. The principal trade organization is the Society of the Plastics Industry.

*Opportunities and problems*

There is agreement that current background technology, from which industry growth must be derived, is inadequate for opening up the opportunities for new uses of composites. In all classes of applications, there is a need for better standards and

specifications, improved manufacturing methods and reliable inspection and testing techniques.

There is a very broad potential especially for mass production, where the lack of adequate specifications, performance standards, uniform processing methods inhibits economically and technologically beneficial uses of composites. For the entire industry, but especially for small operations, there are also problems relating to waste disposal, recycling and handling of toxic materials such as styrene.

Solutions to these problems offer the possibility of improved design, higher strength, lower cost, and better life-cycle performance of components, leading to wider acceptance and use of composites with resulting large economic benefits. Although there is a large body of proprietary technology, the generic technology opportunities cover the entire industry.

The participants agreed on the desirability of R&D in the following technical areas:

1. Basic studies relating to the processes in large scale use for making composite objects.
2. Extensive testing of representative composites to establish their life cycle performance and collection of data to guide design work to utilize them.
3. Development of test methods, inspection methods and design methods.
4. Fundamental studies of component interfaces and fracture analysis.
5. Methods of recycle or disposal of composite materials.

*Reaction to cooperative technology program*

Participants saw merit in the concept and expressed a strong desire for continuing discussion to develop the program. Non-industrial workshop attendees, representing the group that is likely to perform most of the R&D, had an even higher level of interest. Two-thirds of the industrial representatives estimated that their firms might contribute a mean of $32,000 per year to support a CTP in composites.

The activities of a Cooperative Technology Center (CTC) were given the following priorities (in descending order): Research and development (high); technical training (high); information services (moderate); physical demonstrations (moderate); and labor and management education (low).

There was a strong feeling that industry should control project selection, that CTC member companies should have special privileges, and that inhouse R&D facilities were essential.

The use of existing centers at universities was strongly endorsed. Current technicial leadership in the universities is well regarded and should be given more support to expand and accelerate current work. The industry is interested in R&D and industry-university cooperation is good. Some university programs already have broad and substantial industry support.

It was felt that $10–15 million of incremental support was needed for 3–5 years in several centers to make a meaningful impact—accelerate technology, provide trained people, improve technology transfer and meet the challenge of foreign technology. Attitudes were generally positive and forward looking with great interest in the next steps to be taken.

*Prospects for cooperative technology program (CTP)*

There was a general consensus that significant development opportunities in this industry need more effort along the lines of the project areas listed above. It was agreed that the leadership for developing the CTP has already come from the research community and need not await further action by industry (as proposed by DOC). A number of survey and workshop participants urged the establishment of a CTP merely by the government's joining in or contributing to the funding of existing research institutions and programs which already have industry sponsorship and support rather than by establishing an entirely new organization.

While a multi-million dollar program over five years might be needed to make an important commercial impact, a start should be made on a scale commensurate with the actual industry contributions and commitments. Even modest government funding would permit a newly established center to offer more and better service to its sponsors and thus enable it to attract wider and more general support from industry. With the availability of government funding, enough additional centers will be established to approach the research, training and technology transfer capacity needed to make a significant improvement in the growth rate and ultimate potential of the industry.

*Potential benefits*

It is apparent that the development programs suggested would open up expanded opportunities for use of composite materials, especially through improvement in

physical properties, reduced processing costs and improved product standardization. This includes the exploitation of the light-weight, high-strength prospects.

Thus, automotive use of composites is conservatively estimated to increase by 40 to 60 pounds per car between now and 1985. At current costs of approximately $1 per pound and 10 million car production this comes to a volume increase of 400 to 600 million dollars. A Cooperative Technology Program by promoting more optimum development of composites could therefore directly influence in the near term business in the range of $200 million or more. In the longer term to 1990 the margin of increased volume in automobile application which could be directly influenced by a Cooperative Technology Program, would be in the range of $1 billion. In addition, substitution of the composite material for steel would save 30% of the energy required to produce the material. The energy saving in material for composite versus aluminum would be 65 percent. Finally, the use of composites through providing lighter weight vehicles provide for substantial operating energy savings. These at a composites use of 300 pounds per car (possible in 1990) could save 2 billion gallons of fuel per year.

*Funding estimates*

Assuming about $60,000/year for professional and $30,000/year for non-professional staff, the first five projects are estimated to cost:

[Dollars in thousands]

| Project area | 1st year | | 2d year | | 3d year | | 5th year | |
|---|---|---|---|---|---|---|---|---|
| | Amount | P/N [1] | Amount | P/N [1] | Amount | P/N [1] | Amount | P/N [1] |
| 1—Basic studies | $200 | 2/2 | $400 | 3/6 | $500 | 4/8 | $800 | 5/12 |
| 2—Life cycle performance | 300 | 3/4 | 300 | 3/4 | 300 | 3/4 | 500 | 4/6 |
| 3—Test, inspection, and design methods | 200 | 2/2 | 500 | 4/6 | 500 | 4/6 | 600 | 6/6 |
| 4—Component interfaces and fracture analysis | 200 | 2/2 | 500 | 5/5 | 500 | 5/5 | 600 | 6/6 |
| 5—Recycle methods | 200 | 2/2 | 300 | 3/4 | 300 | 3/4 | 500 | 2/8 |
| Total | 1,100 | 11/12 | 2,000 | 18/25 | 2,100 | 19/27 | 3,000 | 23/38 |

[1] Professional/nonprofessional MY.

*Participants.*—Total 74 including: 45 Industry; 14 Universities; 1 Southwest Research Institute; 2 Society of the Plastics Industry; 9 U.S. Government; and 3 IRI/RC.

## *Welding and joining*

*Summary*

Welding is a manufacturing process, not an industry. It is so pervasive throughout U.S. industry that it is difficult to estimate its total economic impact. The difficulty is compounded by the fact that the welding process itself comprises, in many cases, one or more stages within a larger multistage process. Nevertheless, the following data are significant in considering its economic magnitude:

The dollar volume of seven principal industrial areas where welding is used extensively is as follows:

*Approximate 1978 dollar volume*

[In billions]

| | | | |
|---|---|---|---|
| Automobiles | $81 | Steel | $43 |
| Aerospace | 20 | Aluminum | 6 |
| Structural fabrication | 6 | Pressure vessels | 6 |
| Shipbuilding | 7 | | |

By contrast, annual shipment of welding equipment and consumables is $3 billion.

The shipments by welding apparatus manufacturers to consumer industries are expected to reach $1.5 billion in 1979, a 14% increase over 1978 shipments with real growth, discounting inflation at 6%.

*Export-imports* [1]

Continuing strong worldwide demand for welding apparatus to join metals, increase productivity and reduce labor costs will directly benefit U.S. suppliers for some time to come. U.S. produced welding apparatus is well regarded in most developed and developing countries throughout the world.

U.S. exports of welding equipment account for about 20% of the industry total output. In all, 126 foreign countries in 1978 imported an estimated $244 million in welding equipment, up 19% from 1977. Imports—while only 4% of consumption—are also rising. The dollar volume of imports of welding equipment in 1978 was estimated at $48 million, up 43% over 1977. West Germany continued to be the main supplier.

Two primary welding institutions are the American Welding Society (AWS), a professional society with over 25,000 members and the Welding Research Council (WRC), a research association consisting of over 400 companies supporting 60 research projects and using a diverse system of specialized committees and task groups. In addition to these engineering organizations there are over 500,000 welders in the U.S.

*Opportunities and problems*

The welding leverage for improved productivity in the industrial areas listed above is very large. For example, in welding two-inch thick aluminum plate Alcoa was successful in developing a special new welding process which reduced 46 weld passes to two passes—a 96 percent reduction. By extrapolation, 8-inch-thick plate used in spherical liquefied natural gas tanks might be welded in 35 passes instead of the 500 to 600 passes using conventional techniques. A laser welding development at United Technologies shows potential for very major reduction in the approximately 60,000 man-hours required for welding re-enforcing rings in submarine hulls.

Each of the major industrial areas listed earlier provides many opportunities for technological development. The study team developed a list of 13 major categories of needed research. Interviews with university researchers yielded a list of 27 specific projects. The lists were backed up by more detailed project descriptions. Three separate work groups discussed the proposals and decided on the following five priority items out of the major categories list: (1) Weld process control and automation; (2) weld discontinuities and code acceptance standards; (3) weldability, base and weld metal; (4) welding of heavy sections; and (5) improved automated non-destructive inspection.

A problem area which is recognized and needs to be more aggressively attacked is that of welding safety and health. Not only is a safe and healthy working environment a personal requirement for the individual worker but it is also a prerequisite to improved worker productivity

Another problem area concerns productivity in the steel industry where production costs have risen faster than productivity opening a widening doorway to foreign competition from both raw and fabricated steel. In pressure vessels worldwide overcapacity and extreme competition from other countries have resulted in the U.S. losing its market and technical leadship in this area. Shipbuilding has the same problems (productivity, productivity, productivity) together with excessively high labor turnover.

*Reaction to cooperative technology program*

The welding and joining workshop was addressed by a broad spectrum of those concerned with this area. The workshop presentations included: The aluminum and non-ferrous industry. The steel industry. The structural fabrication industry. The shipbuilding industry. The pressure vessel industry. The welding supplies and equipment industries. The automotive industry. The American Welding Society. The Welding Research Council. The Dean of the Graduate School of Engineering, Lehigh University.

In addition, there were many others present representing industry, universities and institutions. There was a clear consensus that the cooperative technology concept offered significant benefits to the industry, academia and the country, that the identified areas of R&D were important to productivity improvement, and that industry support for the Department of Commerce proposal was obtainable. It was thus concluded that a Cooperative Technology Program in the Welding and Joining area was a desirable target, assuming that a suitable mechanism and adequate funds for such a program would be available. Those present from the Welding Research Council felt that the Council represented, from industry's viewpoint, the best management structure for the Cooperative Program.

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[1] U.S. Department of Commerce. "1977 U.S. Industrial Outlook."

The interest in the Program is shown by the fact that, with the possibility in mind that early cooperative technology funds might be available, the Welding Research Council together with three universities (Lehigh, Ohio State and the Colorado School of Mines) put together definitive project proposals in the three areas: Materials for Welding (consumables); Process Development and Controls; Design and Performance of Weldments.

The Council submitted a proposed plan for projects at these university "Centers of Excellence" in a letter dated August 10, 1979, to the Director of the Office of Cooperative Technology, as outlined below:

PROJECTS AND COSTS

| Center and project title | Objective—why project needed | Thousands per year | |
|---|---|---|---|
| | | Cost | Estimated benefits |
| Colorado School Mines: | | | |
| Improve properties electroslag welds | Federal HWA forbids use on highway bridges | $80 | $20,000 |
| Weld cladding to reduce wear | Reduce maintenance costs in industry | 90 | 35,000 |
| Develop superior weld fluxes | Improve weld metal service properties | 80 | 20,000 |
| Total | | 250 | 75,000 |
| Ohio State University: | | | |
| Fusion welding feedback control and automation. | Reduce defects, improve productivity | 150 | 200,000 |
| Devise more economic methods for welding thick (over 1 inch) plate. | To regain competitive position in international market for heavy weldments. | 150 | |
| Total | | 300 | 200,000 |
| Lehigh University: | | | |
| Evaluate significance of weld defects to service performance. | Provide accurate measure of quality required for selected service to reduce unnecessary rework. | 80 | 200,000 |
| Measure weldability of hi-strength microalloyed steels. | To extend use of economical microalloys to higher thicknesses and yield strength. | 90 | 10,000 |
| Improve strength of resistance welded light gage high strength, low alloy steel. | Increase service properties welded joints permitting lighter weight and improved fuel economy of vehicles. | 80 | 50,000 |
| Total | | 250 | 260,000 |

Government support is needed for the above projects because welding is a disaggregated industry which does not have the capital to invest in projects which would mostly benefit the users of the process. Benefits from the Welding Research Council's starting program are estimated at $535 million per year. Also, the Council offers to provide 20% or $160,000 for the first year budget of $800,000.

*Prospects for cooperative technology*

The study has shown a range of technical development needs associated with welding and joining which, in the opinion of those in industry, academia and associated technical organizations, should be getting more development effort than that now in effect.

It is also the opinion of the study participants that a number of the development areas and projects would benefit from combined attack by government, industry and academia. The primary function for government would be to provide seed money and to share the cost of selected development projects. The role of industry would be to lead in determining and managing the technical development program as well as to supply a non-profit corporate structure together with some of the operating funds for carrying out the programs. The universities would participate in determining project targets, would be a primary research performer and would play the major role in providing trained engineers needed by industry.

The research categories which emerged from the industrial survey are:

(1) Welding process and automation;

(2) welding of heavy sections by high deposition process or by new processes that minimize weld metal;

(3) automated and improvement of NDI;

(4) improved electrodes, coatings, fluxes, and gases;

(5) significance of weld discontinuities to service performance;
(6) weld discontinuities—significance in codes and standards;
(7) weldability-base, weld metal, and heat affected zone (HAZ);
(8) weldment design;
(9) process development;
(10) corrosion of weldments;
(11) adhesive bonding;
(12) economics and productivity of welding; and
(13) safety and health.

The workshop proceedings which are given in the Appendix to this report list specific projects submitted in these categories. The five priority areas selected by the workshop were given earlier.

*Benefits*

As mentioned above, benefits from the initial three university programs are estimated at $535,000,000. Examples of very substantial increases in welding productivity were given earlier in respect to heavy aluminum plate and submarine hulls through application of new technology.

Welding of large diameter pipe for transmission lines has been done for years by manual welding. This method permits the addition of 80 to 100 pieces of pipe to the end of the line each working day. A mechanized system has now been developed which makes it possible to add 100 to 140 pieces of pipe per day. The mechanized process has been shown to be 30 to 40% more productive than manual welding while providing quality leading to less repair and fewer cutouts. One of the projects proposed for the Cooperative Technology Program is automation of arc welding in manufacturing. It is apparent from the automation of pipe welding that similar gains in productivity can be had in automation of manufacturing arc welding. These gains would show up in the wide range of large industries listed earlier, leading to substantial economic benefits. It is apparent from the few examples given that the economic benefits will be of very large magnitude easily running into hundreds of million of dollars.

*Study participants.*—Industry, 34; universities, 8; government, 7; industrial survey team, 4; American Welding Society; Welding Research Council; IRI/RC.

## *Textiles*

*Summary*

*The industry*

Textiles is a large and mature industry employing almost a million people and creating $44 billion of shipments annually. It uses over three billion pounds of cotton, 9 billion pounds of synthetic fibers and almost 100 million pounds of wool. Textile imports and exports are almost in balance at about 400 million pounds annually, but for apparel there is a large negative balance, with imports exceeding exports by about 650 million pounds. The growth rate of the domestic textile industry has been about 1 percent annually since 1970. In spite of the fact that labor rates are significantly less than for U.S. manufacturing industry as a whole, so also is the return on sales and on capital.

The most significant impacts of foreign competition are in moving major markets overseas (the apparel companies) and in limiting prices to the extent that regulatory costs and capital recovery are severe problems.

A good deal of the specialized machinery used by the industry is manufactured in the European Common Market. Industry spokesmen presented a mixed viewpoint on the question of whether this hampered their operations.

*Opportunities and problems*

It is impossible to overemphasize how much, within the industry sector, the thinking of the R&D community, industry and academe alike has been influenced by the environment of government regulation and rising energy costs. For example, a number of sophisticated approaches to the slashing, dyeing and finishing operations have as their only motivation the alleviation of such pressures. To be sure, proprietary projects with exciting new product possibilities undoubtedly exist, but would probably not be disclosed to this study.

Other industry problems which were prominent in the minds of the R&D executives, but which are not amenable to direct technical attack by their organizations, include the movement of the apparel industry and the textile machinery industry overseas, the existence of excess plant capacity in the world, capital costs which are higher than the current return on capital, shortage of first-rate technical people, etc.

Thus, in the typical division of R&D objectives into cost reductions and product improvements, the emphasis on projects recommended to us was on cost reduction. And as mentioned above, this industry sees its worst cost problems in the area of regulations and energy.

For example, the American Textile Manufacturers Institute estimates that capital requirements generated by the regulatory environment will add from $6 to $17 billion over the next five years to the industry capital budget. The total cash flow of the industry over that period of time might be chewed up by these requirements. Put another way, the cost of that capital could add about $100 to $300 million to costs the first year and similar additional amounts each succeeding year over the five-year period.

Improved communications between the textile industry and the apparel industry could have significant benefits to both. The apparel industry is severely trade impacted and highly disaggregated. Cooperative efforts could provide better communication, a better coordinated industry, and thus slow the movement of this market for textiles overseas.

*Reaction to the cooperative technology program*

There has been a mixed reaction to the Cooperative Technology Program from the textile industry. First, there have been opinions expressed both in favor of acceptance of the general idea or categorically opposed to any activities of this nature involving the government. The majority of R&D executives feel that there were areas where cooperative R&D could make an industry contribution but reserved judgemnt on the management aspects of the program. They did indicate a desire to have a continuing dialogue in an effort to specify projects which would have industry acceptance.

Matters that were of particular concern to industry representatives:

(1) That project selection be clearly the province of industry. (2) That organization and management of the program be streamlined from the presently indicated form. (3) That domestic industry be able to benefit from technology developed by the program before it leaks overseas. (4) That domestic industry have insurance against antitrust problems that might arise from a cooperative effort.

Many industry representatives also pointed to the need for non-technical measures to assist the industry such as investment incentives and assistance with regulatory requirements.

*Prospects for cooperative technology*

Apart from concerns about the nature of the program it appears that there are significant opportunities for a Cooperative Technology Program to contribute to the industry. These opportunities include needs for new technology in regard to environment, health and energy costs, which would contribute to this industry and its customers in their competition with foreign companies. These areas are especially suitable for Cooperative Technology since they do not relate to specific product developments, are important to all segments of the industry and have the potential for industrial benefits in the hundreds of millions of dollars. They received most emphasis by the industry representatives contacted.

It should be noted that industry supports a number of existing cooperative development programs based at the universities and elsewhere. This current structure should be given maximum use in implementing a Cooperative Technology Program with D.O.C. It is this existing structure which has been cited as one reason for opposition to the concept of the Cooperative Technology Program by a segment of the industry that feels that such a program is not needed.

Further study is now being given to certain specific projects recommended by industry members at the recent workshop, plus certain others to be presented for industry consideration in the future. Of the large number which were suggested these are presently being refined:

*Environment and health.*—Analysis of trace toxic chemicals. Identification of the Byssinotic agent in cotton.

*Energy conservation.*—New slashing processes. Energy savings in dyeing and finishing.

*Cost improvements.*—Color control in dyeing. Jet printing.

The benefits from environment and health projects relate to possible additional industry costs of billions of dollars in meeting regulatory requirement. The cost of meeting the cotton dust standard alone has been estimated to be $300 million annually. The energy per pound spent on dyeing and finishing over 10 billion pounds of fibers also concerns hundreds of millions of dollars of industry cost, not to mention the problem of controlling the toxic chemical used. Substituting foam

carriers for water, radiation curing for thermal curing, and reuse of dyestuffs have the potential for saving a significant fraction of this cost.

The total annual production of prints is of the order of 3 billion linear yards annually. Jet printing technology has the potential of saving from 3 cents to 10 cents per yard, thus providing potential annual industry savings of more than $100 million, if a way can be found to solve government-industry differences on how to conduct the program.

Savings from improved color control are difficult to quantify since the program impact will be to improve the functioning of the apparel-textile industry's interface. Nevertheless, the ability of apparel industry to function more effectively vis-a-vis its competitors using domestic textiles should have a major beneficial impact on the textile industry as well.

ESTIMATED COSTS—R. & D. PROGRAMS

[Thousands of dollars]

| | Year— | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| 1. Environment and health | 400 | 600 | 900 | 900 | 900 |
| 2. Energy conservation | 500 | 700 | 1,050 | 1,050 | 1,050 |
| 3. Cost improvements | 1,000 | 1,500 | 2,000 | 2,000 | 2,000 |
| Total | 1,900 | 2,800 | 3,950 | 3,950 | 3,950 |

*Participants in the survey.*— 19 industrial firms; 6 universities; American Textile Manufacturers Institute; Institute of Textile Technology; Textile Research Institute; and IRI/RC.

*Powder metallurgy*

*Summary*

*The industry*

Using quantities of iron powder produced as an indicator, the powder metallurgy industry has experienced an average annual growth rate of 7 percent in the last 18 years. Sales of powder metallurgy parts last year were about $1 billion, with two-thirds of finished parts used by the automobile industry. About 10 percent of the 12,000 people employed in the industry work on powder production.

Iron powder represents 20 percent of sales value and 80 percent of volume of powder shipped. Other than iron, metal and alloy powders include stainless steel, copper, brass, bronze, aluminum, nickel, cobalt, tungstem tantalum and titanium.

Although virtually every industry uses finished powder metallurgy parts, major consumers are automotive, appliances, industrial machinery and business machines. Powder metallurgy offers important advantages over competing processes for manufacturing certain components. There is a significant cost saving for many parts. Other advantages include energy efficiency, materials conservation including re-use of scrap, materials efficiency as a "net-shape" process and minimum environmental problems. The process also lends itself to mass production and low labor input.

There are few very large independent fabricators, the largest operations being captive in large corporations. Thus the industry structure of smaller fabricators is compatible with the Cooperative Technology concept.

The major trade organization is the Metal Powder Industries Federation (MPIF) which comprises six specialized member associations. MPIF covers the industry spectrum from powder producers to finished product manufacture; it also includes process equipment and tool manufacturers as well as major users of powder metallurgy products.

Therefore, MPIF speaks with authority for the entire industry. MPIF plans to form a non-profit corporation to conduct development programs. There are several universities with background and interests in powder metallurgy R. & D. They include Michigan Technology University, Drexel University, University of Pittsburg and MIT.

*Opportunities and problems*

Strong potential for industry development exists in these broad areas: Market expansion; improved testing and evaluation procedures; programs on powder raw

material; manufacturing process design for improved productivity; and education and technology transfer programs.

Within these broad categories, there was agreement that the top-priority, maximum impact projects were: (1) Technology transfer; (2) powder consolidation and shape-making capabilities.

The first project would address the urgent need for better understanding of powder metallurgy within the engineering community. The second project could have substantial economic impact by reducing the technical limitations to design, manufacture, and wider use of P/M parts. It was agreed that all elements of the industry could share and benefit from the results of these programs. Most potential participants favor the idea that more than one CTC should be formed, particularly if the program expands to cover several of the areas listed above.

*Reactions to cooperative technology program (CTP)*

There was general agreement that an appropriately designed Cooperative Technology Program would benefit the powder metallurgy industry and there was unanimous interest in continuing discussion of the means to develop the programs. The two selected priority programs were approved by all participants, with the reservation that it was premature for individual companies to make commitments to these programs and to the CTP in general. However, it was agreed that more detailed definition would be desirable.

Subsequently, Professor Spencer organized two useful meetings, on July 1, and July 25, 1979, with a selected group of industry experts, which provided analysis of benefits, technical approaches, sequence of tasks and cost and time estimates for the two priority programs.

MPIF, through its Financial Board, has taken a strong interest in the CTP and is expected to formally propose that it manage the CTP through a non-profit subsidiary corporation which can handle existing work as well as new CT project and government contracts.

Participant reactions were positive and responsive. A leadership group exists in the industry which could energize the CTP and there is an expectation of industry-wide participation. There are the usual concerns about government interference and control, a workable management scheme, industry involvement at all stages, continuity of funding, finding the right people, self-sustaining capacity of CTC's, etc. There is a general feeling that the entire industry has considerable growth potential that will benefit everyone and that significant benefits can be expected from a good CTP which will attract broad industry cooperation.

*Prospects for cooperative technology program*

Based on industry characteristics and the results of the survey and workshop, P/M is considered to be an excellent prospect for a CTP. The benefits would extend beyond the P/M industry itself to many user industries, of which the most important one is manufacture of automobiles.

A management and research structure already exists in MPIF and the universities. There is general agreement on the two most urgent programs, each of which has been detailed by an informal group of qualified experts. The economic and technical incentives for a CTP are substantial and the feasibility of the selected programs is not in serious doubt. For these reasons, powder metallurgy is a very promising candidate area for CT.

*Benefits*

The industry is now based on a 30-year old technology and concentrates on manufacturing parts in the size range up to 2 lbs. The desire is to develop and exploit the projects listed above to allow a quantum jump to the 10–20 lb. range and thus open up broad applications and increased markets in a variety of industrial areas. Since we are dealing with a $1 billion per year industry, with 12,000 employees, a steady 7 percent per year growth rate, and two-thirds of finished parts going into automobiles, it is clear that improvements in P/M technology would have high leverage and significant impact on other industries. An example dealing with the automotive industry shows the magnitudes of anticipated cost savings originating from the Powder Consolidation and Shape Making Project.

Objective: To increase the average amount (weight) of powder metallurgy parts in an automobile by an order of magnitude (from 10 lb/auto to 80 lb/auto).

Strategy: To develop new or improved means for making larger and more complex "green" shapes from powder, for example, parts such as connecting rods, bearing caps, cam and crank shafts, and fly wheels.

Potential cost-saving: ($210,000,000/yr)—

| | |
|---|---|
| Average cost per pound casting | −$1.00 |
| Average cost per pound powder metallurgy parts | −0.70 |
| Savings per pound | $0.30 |

($10^7$ cars/yr) (70 lb/car) ($0.30/lb) = $210,000,000/yr
At a 50 percent achievement level—$100,000,000/yr.

ESTIMATED FUNDING REQUIREMENTS

| | Shape making task | | Advanced manufacture and nondestructive testing tasks | Total |
|---|---|---|---|---|
| | Capital | Operating | | |
| 1st year | $100,000 | $500,000 | 200,000 | 800,000 |
| 2d year | 100,000 | 500,000 | 400,000 | 1,000,000 |
| 3d year | 100,000 | 500,000 | 1,000,000 | 1,600,000 |
| 4th year | 250,000 | 500,000 | 2,000,000 | 2,750,000 |
| 5th year | 250,000 | 500,000 | 2,000,000 | 2,750,000 |

*Participants.*—Total 34 including: 20 industry; 5 universities; 1 MPIF; 5 U.S. Government; 3 IRI/RC.

*Organic coatings*

*Summary*

Traditionally, products in this industry have been categorized into two distinct types of coatings. Trade sales paints are primarily exterior and interior coatings for houses and buildings, but they also include automotive refinishes, traffic paints and marine shelf goods which are distributed through trade sales outlets. Industrial product finishes or chemical coatings are made to user specifications and sold to other manufacturers for factory application on such items as automobiles, appliances, furniture, metal containers and aircraft. They also include coatings which are specially formulated for such particular properties as resistance to corrosion. Within these major product lines, the industry produces thousands of different products for many diverse applications, substrates and customers.

Since 1966, the value of industry shipments has grown 7.2 percent per annum. The industry experienced high inflation and raw material shortages in 1973 and 1974. Steady demand for paints and allied products is expected to boost 1979 industry shipments to $7.7 billion, an increase of 8 percent over 1978 shipments. These shipments amount to approximately a billion pounds of paint. In constant dollars, industry shipments are expected to increase by 4 percent in 1979 and slightly less than 4 percent a year in the years 1979–83. Industrial coatings account for about half of total industrial sales and they are expected to grow at a faster rate than trade paints.

According to the 1972 Census of Manufacturers, 1317 establishments in the industry operated 1600 plants and employed about 65,000 persons. In 1972, the top four companies (Sherwin Williams, DuPont, PPG and SCM) accounted for 22 percent of sales, the top eight accounted for 33 percent and the top fifty for 64 percent of sales. Only a few firms sell nationwide because of high shipping costs, the difficulty of maintaining production schedules and other distribution problems. Large paint manufacturers thrive primarily by having small pieces of many markets. Thus significant consolidation is unlikely to occur in the near future as proximity to local markets will sustain many smaller paint makers in competition with larger companies, none of which holds a significant share of a single local market.

Primarily due to the high transportation costs, exports and imports of coatings have been minimal. In 1978, U.S. coating exports were estimated to be $225 million, whereas imports were estimated to be about $52 million. These represent 3 percent and 1 percent of total domestic shipments respectively. West Germany is the largest single exporter to the U.S., accounting for 46 percent of U.S. imports, whereas Canada is the largest importer of U.S. coatings accounting for over 40 percent of U.S. exports. In recent years, i.e., 1973–78, imports of coatings into U.S. have grown at an annual rate of 23 percent, a significantly higher rate than the growth in exports of 14.6 percent per annum.

*Opportunities and problems*

U.S. coatings are highly regarded overseas and opportunities should exist for export expansion. However, so far, U.S. industry has not been export oriented due to the high shipment costs and the presence of a large domestic market. U.S. producers have participated in foreign markets primarily through foreign subsidiaries and through extensive cross-licensing. As world markets expand, U.S. producers will face increasing competition from large foreign producers such as Bayer, BASF, CIBA-GEIGY and ICI who derive a large proportion of their sales through export and have initiated extensive product and process research.

Since 1967 the coatings industry has been facing an increased amount of regulation, particularly those petaining to volatile emissions, toxicity and water pollution. These regulations add to a "mandated technical revolution" in the industry, introducing severe operational and economic problems. Moreover, although the U.S. is currently ahead of the world in coatings technology the consensus in the industry is that we are losing our lead and may well fall behind unless we find better ways to cope with the numerous regulations being imposed. Thus, the frequency and urgency of these regulations have caused considerable concern in the industry about its future as it struggles to maintain quality and costs and find suitable substitutes for the coating affected. It is estimated that about 20 to 40 percent of the R&D budget used for testing and reformulation to comply with EPA and OSHA regulations. Capital expenditures on pollution abatement equipment amounted to $5.5 million in 1976 and an additional $15 million in costs were incurred in operating such equipment.

Price increases have been limited by competitive conditions in the industry, rising 3.4 percent a year from 1967 to 1973. Estimated productivity, measured by the gallons produced per manhour, has not increased as much as labor costs. Average annual growth in productivity has been only 2.5 percent since 1966 compared with a rate of 6.9 percent for the industry's total wage bill. As a result, net profit on sales has been consistently low, ranging from 2.52 percent in 1974 to 2.8 percent in 1976, as compared to 4.5 percent for all manufacturing. Consequently the industry spends relatively small sums on capital equipment, generally 2 percent on sales. Also, according to the National Paint and Coatings Association (NPCA) R&D expenditures for new products were 2.2 percent of sales in 1977, well below the 2.8 percent spent by the total chemical industry.

*Reaction to cooperative technology program*

Highlights of the industry study revealed management as wary of further government involvement in its business and staunchly in favor of free market competition based on proprietary technology. There was real concern in respect to a Cooperative Technology Program that this could involve further government red tape, controls, and other requirements. However, the study also revealed serious management concern over the impact on the industry of current external forces—environmental and other regulations, raw material supply problems and energy conservation needs—especially the serious impact of the environmental regulations. These impacts tended to induce in management a willingness to examine the possibility of a Cooperative Technology Program provided the Program would be supported (and probably managed) by the National Paint and Coatings Association of which the vast majority of the companies in this industry are members.

*Prospects for cooperative technology*

Within the organic coatings industry there are significant development needs which should be receiving more effort than is currently in effect. These needs are primarily the result of the "mandated technical revolution" brought about by legislative controls designed to alleviate environmental concerns. Whereas one technology (solvent based coating systems under 70 percent solids) in 1970 accounted for over 97 percent of U.S. coatings demand, there are now six "emerging technologies" which are undergoing widespread evolution as potential candidates to replace traditional "low-solids" solvent based coatings in almost all end use markets.

These "emerging technologies" are: Solvent systems over 70 percent solids (including hot melts); two-part catalyzed systems (including polyester/styrene); emulsions and lattices; water-soluble and colloidal dispersions; powder coatings; and radiation-cured systems.

The regulations together with the new technologies are bringing about radical changes in the coatings industry including production systems, market segmentation, production inventory management, product shelf life, allocation of R&D funds and marketing systems.

The highly disaggregated industry is faced with these changes at a time of low profits. Disaggregation, low profits and substantial requirements for technological

change strongly support serious consideration of joint development efforts in non-proprietary areas.

As discussed earlier, the industry has serious concerns about becoming involved with the Federal Government in a Cooperative Technology Program. Nevertheless, with the feeling that prospects for much relief from environmental regulations (justifiable or not) are not good, that improved government-industry relations are certainly desirable and that the technical development problems facing the industry are substantial in overall magnitude, the industry believes further dialogue in respect to a Cooperative Technology Program should be pursued. While a list of suggested programs and projects emerged from the survey, the workshop concluded that further study of projects would be required before adequate approval could be obtained from a reasonably broad segment of industry members. Current suggestions include:

Positive Alternatives for Achieving Objectives Sought by Regulatory Agencies. These include: (a) Alternative, acceptable methods for handling current coatings; (b) alternative coatings and methods for handling them; (c) toxicity evaluations.

Improved electrostatic spray technology—

To reduce oversprays and improve uniformity of coatings in both current coatings and new coatings (such as water-based). This development would improve productivity while reducing costs and conserving materials.

Development of Non-polluting Means to Combat Mildew and Fungus Attack on Paint. "Painted surfaces in humid atmosphere are often severely attacked by mildew and fungus which discolor and degrade the film. One aspect of the problem is to find anti-fouling agents which are long-lasting and non-toxic."

Development of new technical-economic data on the risks-benefits-costs and problems of meeting the regulatory mandates. This data could be useful in dialogues with the regulatory agencies. "Particularly troublesome, according to industry, are the contradictions among the various regulations which in effect say "You must eliminate this material or process" on the one hand, but then assert "You can't introduce any new material or process until you prove absolutely it is harmless to man and the environment." The multiple problems created by the Environmental Protection Agency regulations are just beginning to have a serious impact on the industry. Individual company efforts cannot adequately simultaneously handle these problems."

Development of new, rapid methods of reliably detecting and predicting the way a coating will deteriorate. "The two-to-three-year evaluation time required to validate any improvement or change in a coating system is both costly and a serious constraint on getting changes and improvements adopted commercially."

Development of substrate specifications for coatings application. "The most important single factor in the performance (durability) of a coating is the character of the substrate on which it is applied. A joint effort with substrate manufacturers, coatings manufacturers and users of the substrates and coatings could provide suitable substrate specifications which in turn could yield major improvements in coatings performance."

The task the Scientific Committee of NPCA has taken on is one of getting widespread recognition among industry management and research directors that: (1) There are vital programs that are not now being tackled that need doing. (2) That new technological/economic data and information can be brought to bear on these problems to the benefit of the industry and its customers. (3) That the major programs that are not being tackled are non-proprietary and non-competitive, and are of such nature that they can be coped with only via cooperative effort. (4) That the economic impact on the industry, its customers and the nation can be very large.

When these four aspects of the potential for Cooperative Technology are widely recognized the industry will be ready and able to fund the projects and programs involved. If ways can be found to bring into the cooperative venture other elements that have a substantial economic stake in the results, funding potential can be greatly increased. These elements include users, raw material suppliers and equipment manufacturers.

*Benefits and costs*

The potential improvement in coatings performance and reduction of losses from corrosion is estimated to be $2 to $6 billion a year for the nation. The release of industry research from inadequate individual efforts on regulatory problems is estimated at $20 to $30 million annually and the value of more rapid coatings evaluation procedures is at least a like amount.

Preliminary estimates of the cost of the first five years of a CTC are $3 to $4 million per year. Funding half of such a program would be a very large step for the

NPCA (roughly doubling its current budget). Thus there is a major "selling job" to develop conviction that new technology can change things and that the stakes are real. A tentative program is described on the attached chart.

## INDUSTRIAL COATINGS—COOPERATIVE TECHNOLOGY CENTER, TENTATIVE PROGRAM SUMMARY—PHASE I

| Program title | Talents required | Time | Man-years | Estimated cost | Facilities needed | Probability of success | | Benefits | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Technical | Business | Who | How |
| 1. Specifications for cold-rolled steel. | Phys. and process met. anal., phys., surface chem., physics. | 2–3 yrs. | 10 | $1.5MM or $500M/yr. | SEM, X-ray Difract. microprobe, $500M. | 90 percent | 60 percent, 3 yrs., 80 percent, 5 yrs.. | Coatings makers, users, and U.S. consumer. | Better corrosion resistance of products. |
| 2. Positive alternate for Regulations. | Toxicology, chem. pharmacology. | 3–5 yrs. | 15 | $2.8MM or $500M/yr. | Tox. Lab., GC-Mass., Spec., HPLC, NMR, IR, etc., $500M. | 50 percent, 3 yrs., 80 percent, 5 yrs.. | 50 percent, 3 yrs., 70 percent, 5 yrs.. | Environment, consumer, coatings, user and manufacturers, U.S. economy. | Reduced cost to achieve clean and safe environment. |
| 3. Early evaluation of coatings. | Surface, analytical physical, chemistry physics. | 3–5 yrs. | 10 | $1.5MM or $300M/yr. | Same as programs 1 and 2. | 50 percent, 3 yrs., 70 percent, 5 yrs.. | 50 percent, 5 yrs., 70 percent, 10 yrs.. | Coatings users, manufacturers U.S. consumer. | Faster change in coatings system to meet environment and cost needs. |
| 4. Phys. Chem. of High-Solids and Low M–W Systems. | Physical chem. Surface chem. Physics. | 2–3 yrs. | 6 | $1.0MM or $300M/yr. | Rheometers, particle size measurement, $200M. | 60 to 80 percent, depending on system. | 50 to 60 percent | Coatings manufacturers and users U.S. economy environment. | More competitive coatings in world market and faster change. |
| 5. Comprehensive Information System. | Chemistry Library science | 2 yrs. | 4 | $600M or $300M/yr | Computer, files | 100 percent | 100 percent | Whole coatings industry | Faster diffusion of technology. |
| 6. Particle behavior in electrical field. | Physics, phys. chem., surface chem., elect. engr. | 2–3 yrs. | 5 | $1.0MM or $300M/yr. | Spray system | 60 to 80 percent | 60 to 70 percent | Coatings manufacturers and users, equip. makers. | Lower cost, less waste, reduced effluents. |
| 7. Designs that facilitate painting and repainting of steel. | Civil engr., structural engr., architects. | 2 yrs. | 3 | $200M or $100M/yr. | | 80 to 90 percent | 60 to 70 percent | Coatings manufacturers U.S. public. | Better use of material resources, lower costs. |
| 8. Anti-Mildew and Fungal Agents. | Microbiologist org. and physical chemistry polymer chemistry. | 3 yrs. | 6 | $1.0MM or $300M/yr. | Biology lab, polymer lab | 40 to 50 percent | 40 to 50 percent | Coatings manufacturers, U.S. customers. | Longer life of paints, lower cost. |
| Approximate total | | 2–5 yrs. | 60 | $10MM or $3MM/yr. | $2MM equipment, $2MM leasehold improvements. | | | | |

*Participants in the survey.*—36 Industry; 4 Universities; 9 Government—6 NBS, 1 DOC, 1 EPA, 1 NSF; 5 IRI/RC; National Paint and Coatings Association; Paint Research Institute; and Federation of Societies for Coatings Technology.

## *Semiconductors*

*Summary*

The American electronics industry, with sales in the hundred billion dollar range, accounts for roughly 10 percent of U.S. GNP and employment. The driving force for this industry is the semiconductor, and advancements in semiconductor technology lead advancements in the entire electronic business and into nearly every facet of manufacturing.

The consumption of semiconductors in the U.S. in 1979 is between $6 and $7 billion and the growth of semiconductor usage will range from 10 to 20% annually over the next five years.

The most important part of the semiconductor business is the integrated circuit portion, where many devices such as transistors are placed into a semiconductor device, or "chip." U.S. factory shipments of these integrated circuits will exceed $3 billion in 1979. This figure is expected to reach $8–10 billion by the mid-1980's.

Almost every segment of U.S. industry has plans which depend on their being supplied adequately with the latest semiconductor products. The automotive industry, for example, will require $400 million per year of integrate circuit devices in the 1980's. However, the U.S. semiconductor producers, and the favorable export balance are being threatened by massive development efforts from overseas.

With a full awareness of the basic impact of semiconductors and computers on the entire economic and social spectra of the industrialized nations, the technically advanced overseas countries have launched very large scale development efforts (on the order of $2 billion in development over the 1977–82 time period) in order to catch up and to pass the United States. The huge markets for computers and associated semiconductor products are the targets. In 1978, Electronic Computing Equipment together with Electronic Systems and Equipment, provided the U.S. with a $4 billion trade surplus. The magnitude of this surplus, taken together with the size of our adverse trade balance, underscores the importance of maintaining our strength in high technology electronics products.

*Opportunities and problems*

The semiconductor industry is an aggressive, "heads-up" industry made up of many success-oriented firms. Continued strong technological development by these firms will have major impact on the ongoing computer and electronic revolution in this country and therefore on the economic future of the country. This impact runs an extremely wide range from office equipment and communications to automobiles and household products. A Cooperative Technology Program can capitalize on this strong base and use it to stand off overseas industry/government consortia.

A problem for the industry is that technology costs are rising at very high rates. Thus, technology advancement has reached the point where new developments (processes and equipment) require very much larger expenditures than during the earlier development stages. An Electron-Beam direct-write imaging machine can cost, for example, one and one-half million dollars or more, replacing an optical machine which cost $100,000 in 1976. These increased development costs make it increasingly difficult for new companies, or individual present companies (except the largest), to carry the costs. Foreign governments, recognizing this, have formed cooperative efforts to provide such funding and avoid duplicate efforts.

There are substantial D.O.D.-financed development programs in the semiconductor area. The problem is to coordinate non-defense development efforts with the D.O.D. work. The opportunity is to achieve more efficient national development effort.

*Reaction to cooperative technology program*

The industry attitude toward a cooperative technology program is generally positive. The industry is aware of both ongoing development needs and the danger from overseas consortia. However, the industry has strong views in respect to certain principles of a cooperative program. These can be summarized as follows:

1. There must be adequate assurance that a reasonable cooperative technology program will not be upset by the Justice Department or the FTC.
2. University elements associated with the technology should be strengthened to provide increased research efforts and especially to train graduate engineers and scientists for technical positions in industry. At the same time there is a need to

make sure that the universities are responsive to industry views in the matter of developments.

3. The industry would not be interested in a Cooperative Technology Program which had associated with its bureaucratic red tape and complexities and/or a large parallel government bureaucracy. The development funds should go into the development effort with minimum government bureaucratic overhead.

The areas of potential projects cover many technical disciplines, including chemistry, physics, optics, computer-aided-design, electronics, basic materials phenomena and the like, each of which is at the state-of-the-art. In view of the number of disciplines to be investigated, the magnitude of the development tasks, and considering the value to the nation of continued strength in the semiconductor area and the size of overseas competitor efforts, it may be advisable for the U.S. to consider establishing a large, central laboratory. This might be along the lines of already established university-based laboratories, such as the Lincoln or Draper Laboratories at MIT or the Jet Propulsion Laboratory at California Institute of Technology, in order to put together a strong enough team covering the wide spectrum of disciplines required to solve the basic development problems. To assist in training engineers for industry, the laboratory would have to be closely affiliated with one or more universities and with industry as well.

As an alternative to one central laboratory, the various projects could be undertaken at a small number (4 or 5) of university "Centers of Excellence" dispersed between East and West. This approach is considered to have the advantage of combining the outstanding need for increase in the supply of scientists and engineers with the need for research. A special separate development effort could be advisable on electron-beam direct-write lithography which would require industrial resources rather than those at the universities. This approach which emphasizes university bases appears at present to be most favored by industry.

It may be that the diverse, multi-component development approach in the United States will be adequate to match overseas competition, provided the efforts of D.O.D. are continued at a substantial level, increased efforts are put behind the "Centers of Excellence" referred to above, and a "coordinating agency" is established to provide analysis and advice for cross-coupling and balance of development efforts. This coordinating agency could be in the government but would have a Board of Advisers from government, industry and academia to provide review and advice and to assess the U.S. situation in respect to competition.

Evaluation of the interest in a Cooperative Technology Program together with evaluation of projects for such a program is continuing actively beyond the June 14th workshop. It is expected that industry's views will be more crystallized by the end of the year.

*Candidate projects for cooperative technology*

Industry representatives identified five technical areas, of which three have high need for cooperative developments because of the magnitude of the task, lack of qualified researchers in many of the industry companies, development time, and the generic nature of the task.

| *Technical area and cooperative development tasks* | *Priority* |
|---|---|
| Design and innovation: | |
| Device architecture | High. |
| Process models | |
| Device models | |
| Design layout aids | |
| Circuit simulation | |
| Materials: Mainly relate to improving material purity and ability to take better measurements. | Medium. |
| Lithography: Advanced lithographic processes (X-Ray, E-Beam, Ion Beam) and Materials and associated tools. | Very High. |
| Processing: | |
| Clean and pure gases and chemicals | High. |
| New processing fundamentals including plasma, ion beam and annealing techniques. | |
| Thin film, surface and dielectric layer pehomena studies | |
| Assembly and test: Various at all stages of preparation and manufacture. | Medium. |

In arriving at detailed plans for a cooperative approach to these tasks, each task would be sifted down to projects with highest payback as well as to projects not already being adequately handled.

The potential benefits of a strong development program in these areas can only be described as extremely large since ongoing strength in this area is of major value to the U.S. in both the international trade area and the domestic economy.

The challenge lies in finding ways in which to overcome the problems referred to earlier: antitrust, red tape, complexity, overall concerted strength. The industrial base is there.

*Estimated project costs*

The proposed projects are assumed to be conducted at universities. Present DOD-funded programs at universities and the industrial firms may or may not duplicate any of these efforts.

| Technical area | Ongoing budget | |
|---|---|---|
| Design and innovation—at 4 to 5 universities. | $1–$2 million each | $5–$10 million/yr.[1] |
| Materials—for 100 man-years/yr | | $5 million/yr.[1] |
| Lithography: | | |
| E-Beam research | $30 million over 4 yrs | $7.5 million/yr. |
| X-ray research | $10 million over 4 yrs | 2.5 million/yr. |
| UV or iron/beam | $10 million over 4 yrs | $2.5 million/yr. |
| Total | | $12.5 million/yr. |
| Process: | | |
| For clean gas/chemical research | | $0.2 million 1st yr. |
| | | $1–$2 million thereafter. |
| Processing fundamental at 3 to 5 universities. | | $3 million. |
| Assembly and test | | $1–$2 million |
| Total | | $27.7–$34.7 million/yr. |

This programs would build up as follows:

[In millions]

| | Total funding | Industry at 50 percent | Government at 50 percent |
|---|---|---|---|
| 1st full year | $4 | $2 | $2. |
| 2d year | $10–$15 | $5–$7.5 | $5–$7.5. |
| 3d year and thereafter (plus inflation factor) | $27–$34 | $13.5–$17 | $13.9–$17. |

*Participant.*—Industry, 34; Universities, 5; Government, 8; National Science Foundation; National Bureau of Standards; Defense Advanced Research Project Agency; Semiconductor Industry Association; Semiconductor Equipment and Materials Institute; Electronics Industry Association; and IRI/RC.

### *Industrial radiation processing*

*Summary*

Industrial radiation processing considered here involves the use of ionizing radiation in the production of important new products and improvements in many existing products. The "radiation industry" is not a well-defined industry but, instead, a small group of radiation source manufacturers combined with a large variety of radiation user companies.

There are currently two primary radiation sources in commercial use. The approximate numbers are: 250 Electron accelerators; 80 Gamma installations.

Annual sales volume of commercial products produced in part by radiation processing method is in excess of $1 billion.

The annual sales of radiation source equipment approximates $30 million per year.

Applications: Crosslinking of plastics; crosslinking of rubber; preparation of certain composites; curing of paints and coatings; modification of textile finishes; and sterilization of biomedical products.

*Opportunities and problems*

The industries whose main activity is associated with this technology present show a growth rate of 25% per year and 1979 is the biggest year they have experienced. Although the principal application areas are crosslinking of plastics and rubber and the sterilization of disposable medical products, new products are also coming on the market. In addition, the technology is being introduced into more nations on an industrial scale. Right now the U.S. holds the dominant position with Japan still a distant second. Japan is, however, planning an aggressive increase in market penetration. Germany had virtually ignored radiation processing but has recently entered the field of chemical and plastic applications with characteristic vigor.

Adoption of radiation processing technology by American industry is taking place but at a pace slower than the optimum. There are several reasons for this state of affairs. The domestic industry today is based on a narrow line of equipment produced by less than ten companies attempting to serve a wide range of industries and applications. Equipment producers, being of relatively small size, cannot finance all of the studies on radiation effects associated with new areas of commercial opportunity and at the same time make substantial advances in radiation source technology. Also, they are too small to undertake extensive industrial education and technology transfer activities required to introduce the technology into a broad range of industries. On the other hand, the companies served by the source producers are, with a few important exceptions, large and diverse in their present process processes rather explore the implications of radiation processing technology. Further, there are relatively few people educated in the radiation processing field so that there is a limited pool of experts entering industry trained to apply existing radiation of processes, much less speed the development of new ones. Additionally, except for the source vendors, there are few architect-engineers who can make detailed processing calculations and designs.

*Reaction to cooperative technology program*

The interviews generated positive interest in the program but also several concerns. These concerns are:

*1. Patents.*—The fields of radiation chemistry, radiation dosimetry, accelerator design, shielding, and some other of the sciences involved in industrial radiation processing constitute a relatively new technology. While this situation affords competitive opportunity to the developers of processes, products, and systems, the struggle for proprietary position (mostly through patents) tends to work against the concept of shared technical programs.

*2. Legal aspects.*—Connected with the patent issue are the legal problem cited in most interviews regarding antitrust aspects, restraint of trade, and the association of companies of the same industry working together. Some were even concerned about such problems arising from their mere attendance at the May workshop session.

*3. Administrative policies.*—There was considerable concern that federal funding would bind management of a Cooperative Technology Center to administrative policies and procedures which would hamper the implementation of the program.

*4. Information.*—It was felt that, as with other policies of the Center, the publication and documentation policy must protect the interests of U.S. industry. Not only should confidentiality of domestic trade information be honored whenever appropriate, but publication and communication of work done by the Center and its contractors must give preferred position to the interests of U.S. industry. The concern was that foreign governments and industries could acquire knowledge from the Cooperative Technology Program to the disadvantage of American sponsors of the program.

*Prospects for cooperative technology*

It is the view of those surveyed that there are significant development needs in this industry which need more effort. The projects refelecting these needs were listed as follows: Food sterilization; stack gas treatment; electron curing of metal coatings; re-enforced plastics and other composites for the transportation, housing and construction industries; high-power machine production of penetrating photons; nonthermal curing of textile finishes; and process reduction of residual monomers in polymers.

Support for a joint effort on these developments is based on the view that they are impeded by the disaggregated nature and relatively small size of the radiation

source industry, the lack of interest in generic technology by the individual large firms that are potential users, and the special advocacy needs in the food sterilization area.

*Estimated costs and benefits*

Radiation processings is a growing technology with need now for cooperative technology investments to assure U.S. benefits nationally and internationally. The projects proposed in the initial program extend over about five years and are a mix of high value tasks; some of long-term value and others of immediate importance. The investment required by the Federal Government on these Industrial Radiation programs is about $5.4 million over the next five years. Assuming food sterilization opportunities were achieved, the results of this joint expenditure could involve $2 billion per year of important and new worldwide business and could save as much as $50 million per year in energy costs.

The food programs are special because early and significant results can be expected. However, it is probable that Cooperative Technology Programs in this area need not expand in the future.

The project for stack gas treatment could have major and continued impact in the energy industry.

Development of a high power machine type radiation source and the development of new "residue free" monomers will have important market and economic impact on the future size of the Industrial Radiation business.

FUNDING ESTIMATES

[In thousands of dollars]

| Projects | Equipment | Year— | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| 1. Food sterilization | 100 | 300 | 300 | 250 | 250 | 250 | 1,450 |
| 2. Stack gas treatment | 250 | 150 | 300 | ..... | 0 | ..... | 700 |
| 3. Curing of metal coatings | 200 | 200 | 200 | 200 | 200 | 200 | 1,200 |
| 4. Composites curing | 150 | 200 | 300 | 300 | 300 | 300 | 1,550 |
| 5. Source technology | 350 | 100 | 150 | 150 | 150 | 150 | 1,050 |
| Total | 1,050 | 950 | 1,250 | 900 | 900 | 900 | 5,950 |

*Participants in the study*—26 Industrial firms; 4 Universities; 3 IRI/RC.

*Corrosion*

*Summary*

*The industry*

Since economic losses due to corrosion affect many industries, the IRI/RC Study addressed a range of industrial sectors where corrosion costs are particularly significant and where new developments in corrosion control might be especially rewarding. The study covered primary metal producers: steel, copper, aluminum and nickel; major users of fabricated metal: automobile makers, chemical processors, the petroleum industry, transportation and structural fabricators; and makers of corrosion inhibitors. In aggregate, these industries represent a large fraction of the manufacturing sector in the U.S. economy.

A 1978 NBS Report to the Congress includes the following: "As a result of corrosion, users of metal products incur a wide range of costs including painting and other methods of corrosion control, more expensive corrosion resistant materials, premature replacement of capital goods, larger spare parts inventories, and increased maintenance. Some of these expenses (the avoidable costs) could be reduced through the economical best practice application of available corrosion control technology, but lessening the remaining costs (the presently unavoidable costs) would require advances in technology." [1]

The national yearly cost of corrosion is about $70 billion or 4.2 percent of GNP, with an uncertainty of ±30 percent. Of this total, about 15 percent or about $10 billion is considered to be avoidable, that is, subject to reduction or elimination with

[1] "Economic Effects of Metallic Corrosion in the United States," L. H. Bennett, J. Kruger, R. L. Parker, E. Passaglia, C. Reimann, A. W. Ruff, and H. Yakowitz, NBS Special Publication 511–1, May 1978.

use of available technology. The remainder, or about $60 billion per year, is the target for new developments in corrosion control technology.

An additional significant factor is the loss to the nation of energy and materials due to metallic degradation. About 3.4 percent of current energy demand is generated by such corrosion; one-sixth of that is estimated to be avoidable. About 17 percent of our present demand for metallic ores resulted from metallic corrosion; about one-eighth of this, or 2.1 percent of metallic ore demand, was due to avoidable corrosion.

New developments in other technologies, such as energy, environment, materials conservation and food production, are expected to result in new corrosion problems and substantially increased future costs. For example, new energy technologies and new environmental protection systems will utilize metallic materials under high temperatures and pressures in highly corrosive environments.

*Opportunities and problems*

The very large economic costs of corrosion, both that fraction avoidable with better practices and use of available technology, and that part potential controllable with results of new R&D, represent substantial economic opportunity. Avoidable corrosion can be reduced by technology transfer, engineering education, design practice, specifications, inspection, maintenance, etc. An integrated long-term program of basic and applied research can be expected to reduce corrosion that is now considered unavoidable with present technology.

Although there is agreement on the need for and the potential benefits of substantial increase in corrosion R&D, it is to be recognized that there are extensive R&D efforts in this area going on now. There are groups with cooperative industry support such as the Materials Technology Institute, Battelle and certain universities. There are in-house programs and companies in the metal sector, such as the International Nickel Company and U.S. Steel. There are programs in the chemical companies, the coatings companies and the users (such as the automotive companies). And there are the programs with Federal Government sponsorship such as those of NSF, DOT, DOD, DOC/NBS and DOE. The concern is with the need for appreciable increase in effort, particularly in the longer-range, more "generic" area.

Many of the technical problems are very basic in nature, such as getting a better understanding of stress corrosion or finding a mathematical model for different alloys, and so on. They are fundamental research and not development. All of these are long-range and many of them are not being pursued at all or are being pursued with less intensity than engineers believe is necessary. These problems of a basic nature would seem to fall into the sphere of the National Science Foundation. There are many opportunities for further corrosion research of the type appropriate to NSF.

Some problems are of a more practical or applied nature. For instance, there is the deterioration of highway bridges because of inadequate surface sealing with resultant corrosion of reinforcing rods, or the deterioration of highways through erosion of the road surface in winter salting conditions. These problems were mentioned many times by those interviewed, but it was always pointed out that there was little tangible incentive for industry to fund this work. There is a great deal of development being done in this area by the Department of Transportation of the Federal Government and of several states. The highway surface problem is being attacked at a number of Cooperative Technology Centers. Therefore, at present, since such problems are being handled by the Department of Transportation, they are not considered for the Department of Commerce.

A similar situation exists in the concern of the energy industry in respect to corrosion/erosion in high temperature gases, an important problem in coal gasifiers, high temperature gas turbines, and electrostatic precipitators. There are also important problems of corrosion in cooling tower design. These and problems of $H_2S$ in geothermal and oil wells are the concern of and are being addressed by the Department of Energy.

There is a problem of diffused responsibility combined with cost-performance constraints. This is illustrated in the automobile where there are realistic obstacles to potential extension of automobile life. The industry is caught in a tug-of-war between cost constraints and performance requirements. For instance, the materials supplier must be competitive in both material performance and price within narrow limits. The coatings industry is in a similar bind, constrained to a low number of coating applications and limited coatings thickness. The automobile designer cannot provide all of the corrosion-limiting possibilities without unacceptable cost increases. The automobile operator is generally unwilling to pay for comprehensive corrosion protection in the initial price of the automobile, preferring to accept the longer range cost of corrosion damage over the life of the vehicle. Nor is he willing to

operate the vehicle so as to provide reasonable protection against corrosion. Local governments are pressured to provide adequate road salting with little regard for corrosion damage to automobiles. This situation has analogies in other industries where concern with the problem is diffused over several different sectors of industry. The net result is that with these conflicting pressures and fragmented responsibilities, it is difficult to find a leadership group to elicit and develop a sound comprehensive corrosion research program, including the funds to back it.

The research now being conducted is largely in response to the unrelenting pressure to provide adequate performance at competitive costs and the opportunities for near-term market benefits. There is little incentive in industry to support longer-range, higher-risk R&D that offers the possibility of enhancing the generic technology base.

Almost everyone interviewed raised the question of the need for corrosion education in the colleges. Many complained about the absence of any mention of corrosion in the materials courses required of undergraduate engineering students. The criticism is quite valid. However, this a problem that must be attacked by corrosion engineers, their societies such as the N.A.C.E., and their accrediting bodies such as the Engineers' Council for Professional Development. As a Federal issue, university science curricula are in the province of the NSF mission and not a proper justification for a Cooperative Technology Center. A Cooperative Center could assist with training as a corollary arrangement with its primary development activities but could not have education as a prime target.

The question of postgraduate education on the subject of corrosion was often raised during the study, but there seemed to be agreement that although there was need for more work in this area, the problem was being attacked by existing institutions and was probably under control. Even then this subject is not a base for the Cooperative Technology Program.

The idea of a clinical or consulting service was also raised. It seems that the N.A.C.E., the existing institutes, and universities all get inquiries seeking information about corrosion. These usually fall into three types: those where the inquirer can be satisfied by referring him or here to a paper; those where the inquirer needs more time-consuming consultation; and those which might lead to a research program. There is not central location to which all of the inquiries can be referred. There is no doubt that a technology center which would undertake this as one of its tasks and would have the manpower to handle the job would do it more efficiently, but this task alone would not appear to be sufficient justification for such a center. There was also the consideration that consulting engineers did not want to Cooperative Technology organization competing with them.

*Reaction to cooperative technology program (CTP)*

It did not appear that industry would volunteer to put up significant additional money for corrosion research. Although there would be support for Cooperative Technology from those who expect to perform the research (the institutes, the universities, and even industrial laboratories that would like the government to fund the research they would like to do but cannot afford), most would shy away when the question of supplying the necessary funds was raised.

The diffusion of the corrosion problems operates against efficient overall focus on the problems and the formation of comprehensive system-wide attack. The longer-range nature of the R&D efforts suitable for a cooperative approach postpones and beclouds predictable benefits thereby making it difficult for our current industrial system, focused as it is on near-term issues, to provide adequate support. The education and training needs are valid but are not the basis for a Cooperative Technology Development Program. These are then some of the barriers to increased efforts in corrosion R&D and to a Cooperative Technology Program as proposed by D.O.C. It should be added that industry also points out the barriers of taxation and "excessive" application of environmental, health and safety regulations, although these issues were not a subject of the study.

*Prospects for cooperative technology program*

Accepting the need for more R&D effort, particularly long-range and more fundamental work, the central question which was not entirely resolved during the study was concerned with how this should be done and how it should be funded.

Three approaches have been considered:

Expansion of current efforts in the universities, non-profit laboratories, government laboratories and industrial laboratories. Funding would follow current practice.

Organization by industrial sponsors of a Cooperative Technology Program consistent with the DOC concept. Funding would be jointly provided by government and industry with government portion decreasing over several years.

Assignment of major coordinating responsibility for a national program of longer range to an existing government laboratory such as NBS. This laboratory would undertake some in-house R&D but would contract out a substantial portion of its funds to other existing R&D groups such as universities, non-profit laboratories and industrial laboratories. Funding would be primarily by government.

In the time available for the study a general consensus on which of the three approaches was most viable could not be reached.

*Continue as-is*

It was not apparent how one could readily achieve expansion of R&D efforts entirely through present approaches since such expansion would have to be the result of numerous primarily independent decisions in a wide range of companies in different industrial sectors as well as by government and by universities.

*Cooperative technology program*

Adequate industrial support for expanded R&D efforts under the Cooperative Technology Program was not evident from the study despite the recognized need for more corrosion R&D. It was clear that the universities and non-profit institutions would like to have more funding for research but it was not clear that industry would put up the money. Despite the above view of industry support, comments received as a result of circulation of the initial draft of the corrosion study showed that some contacts believed that adequate industry support for a Cooperative Technology Program could be developed provided wider industrial coverage was obtained, industrial contacts were given more time to consider the proposals and that projects put forward were of serious interest to industry. Resolution of this question would call for extending the study.

*Work through Government funding and a "coordinating" Government laboratory*

If, indeed, meaningful increased funding for corrosion R&D could not be obtained by continuing on the present course or by the DOC Cooperative Technology Program and if the Federal Government in assessing the need for increased corrosion R&D concluded that a national effort was called for, then the possibility was suggested of accomplishing this end via government funding with the use of an existing government laboratory to handle the program. The government laboratory would do some work in-house but would contract with other existing laboratories (universities, non-profit laboratories, industrial laboratories) for a substantial portion of the work. Such a program could be incorporated in the program proposals and budgets of the selected laboratory. This arrangement would fall outside of the I.R.I. Research Corporation study and the Cooperative Technology Program of DOC. Nevertheless, the IRI/RC felt that the suggestion should be brought up in view of the expressed need for more innovation in corrosion R&D.

Assuming an expanded technology development program was pursued, the following projects were proposed during the study: Development of corrosion damage prediction methods to reduce the costs of transportation industry corrosion; development of corrosion resistant aluminum alloys by rapid solidification; cathodic protection; high temperature materials for heat recuperation in the steel industry; mathematical modeling of corrosion phenomena; control of tribological corrosion; development of manganese-base sacrifical anode; development of standard test procedures to measure the durability of stainless alloys; development of materials and protection concepts to reduce dependence on strategic materials; materials behavior at high temperatures under conditions of corrosion and erosion; and corrosion of high-alloy weldments.

*Conclusions*

1. The study appeared to cast doubt on the possibility of significant industrial funding support for a Cooperative Technology Program as suggested by DOC. However, this conclusion was questioned by several of the participants in the survey, upon circulation of the draft report on corrosion. In view of this and because of the necessarily limited number of contacts made during the survey, it is recommended that the survey be extended. During this extension period a further list of projects which would provide a proper basis for a Cooperative Technology Program would be solicited and a wider range of industrial companies contacted. Those who have felt the Cooperative Technology Program could obtain adequate industrial support would be asked to participate in the ongoing work.

Should this additional effort fail to indicate sufficient support for a sound Cooperative Technology Program, then the alternative discussed next should be pursued.

2. *Alternative to DOC cooperative technology program.*—The study indicated a need for increased longer-range research in corrosion. At the same time it also indicated that there was not in being a proper focusing mechanism to draw together a comprehensive national program. Indications also are that industry would probably not provide significant support for such a program. Therefore, if the Federal Government wishes to pursue a national effort in corrosion in view of the needs, a federally supported longer-range corrosion research program operating through an existing government laboratory should be considered. Such an effort might well draw in modest industry support. The corrosion R&D should be guided by an advisory committee with strong industry participation.

*Participants.*—Industry, 14; Universities, 6; Government, 6; IRI/RC, 1; Research Institute, 2.

## VII. APPENDICES

### *A. The IRI/RC study team*

*IRI Research Corp.*

The IRI/RC team which carried out this study was as follows:

Dr. Howard K. Nason, president, IRI Research Corp., formerly, president, Monsanto Research Corp.

Mr. Hamilton Herman, Cooperative Technology Study; program manager; consultant on management and technology, former Assistant Secretary for Systems Development and Technology, U.S. Department of Transportation; senior vice president, development, American Can Co.; vice president, R&D and commercial development, AMF, Inc.

Dr. Leo S. Packer, consultant to the program manager; consultant on science and technology and international relations; former VP, R&D, Recognition Equipment, Inc.; Assistant Postmaster General for Research and Engineering.

*Technical team members*

Mr. Leonard C. Afremow, director of research, DeSoto, Inc.

Mr. Robert E. Anslow, director, business development, microelectronics, Rockwell International; formerly, president, Roanwell Corp., New York, N.Y.

Mr. Robert H. Baldwin, consultant on chemical industry ventures, evaluations and programs; formerly, 42 years in the areas of R&D management of chemical manufacturing operations; general manager, operations, chemical division, Sherwin-Williams.

Dr. John K. Bragg, consultant on management and technology; formerly, chief technical officer, Singer Co.; manager of R&D consulting, General Electric R&D Center.

Dr. R. W. Cairns, consultant on management and technology; 38 years in the management of industrial research and development; former Deputy Assistant Secretary of Commerce for Science and Technology; vice president, research, Hercules Research Center; executive director, American Chemical Society.

Mr. H. Ford Dickie, management consultant; former staff executive in the General Electric executive office responsible for production resources; manager of engineering and manufacturing, International General Electric Co.

Dr. William Franta, consultant. 41 years of industrial experience in marketing, production management and R&D experience; formerly director, R&D division, Plastics Products and Resins Dept., DuPont Co.; production manager for Plastics, DuPont Co., marketing manager for Teflon, DuPont Co.

Mr. William Glaser, consultant, Midland Division, Dexter Corp., formerly vice president R&D, Dexter Corp.; V.P., technical director and member of board of directors, Midland Industrial Finishes Co.

Mr. Donald Gustafson, director, International of Gould, Inc.; formerly director of product development, Powder Metallurgy, Gould, Inc.; 26 years in engineering development and field work (17 in powder metallurgy), Gould, Inc.

Dr. Lester Hogan, consultant to the president, Fairchild Camera and Instrument Corp.; formerly vice chairman of the Fairchild board; president and chief executive officer, Motorola Corp.

Dr. George K. Hutchinson, professor of management, School of Business, University of Wisconsin; special emphasis on Flexible Manufacturing System.

Dr. John L. Kukranz, senior adviser, G. D. Searle Co.; formerly senior vice president, Radiographics; V. P. and director of research, Nuclear Chicago Corp.

Mr. David C. Martin, welding and joining/investigator; welding consultant; formerly, chief, welding research division, and manager, department of fabrication, Battelle Memorial Laboratories.

Mr. Joseph R. Martin, textiles/investigator; consultant; formerly director, manufacturing technology, Monsanto Textile Co., director of manufacturing, Monsanto Textile Co.

Dr. Wilbur L. Meier, Jr., automated flexible manufacturing/investigator; professor and head, School of Industrial Engineering, Purdue University.

Mr. Malcolm B. Northrup, semiconductors/investigator; V. P., microelectronic devices, Rockwell International; nearly 20 years of management and engineering positions with Collins Radio Co. and Rockwell.

Dr. Irving A. Oehler, welding and joining/investigator; consultant; formerly chairman of the board and chief executive officer, American Welding and Manufacturing Co.

Mr. George P. Putnam, automated flexible manufacturing/investigator; Illinois Institute of Technology Research Institute, consultant on computer aided manufacturing.

Professor Joseph Silverman, Ph. D., radiation processing/investigator; director, Institute for Physical Science and Technology, University of Maryland.

Mr. Robert E. Somers, welding and joining/principal investigator; welding consultant; formerly assistant manager of product research, Bethlehem Steel Co.; national director of the American Welding Society; fellow, American Society of Civil Engineering.

Dr. Chester Spencer, powder metallurgy/principal investgator, Roanoke Electric Steel; professor and head, Department of Materials Engineering, Virginia Polytechnic Institute and State University, formerly vice president, special metals division; and company director, Chase Brass and Copper Co.

Dr. Eric A. Walker, corrosion/principal investigator; consultant; formerly president, Pennsylvania State University; vice president, Science and Technology, Aluminum Co. of America; head, Electrical Engineering Department, Pennsylvania State University.

Dr. John C. Weaver, organic coatings/investigator; coatings consultant; formerly director of research, Coatings Group, Sherwin Williams Co.

The IRI/RC team worked directly with the Office of Cooperative Technology Staff, National Bureau of Standards, and, in particular, with: Mr. Frederick L. Haynes, director, OCT; Dr. J. D. McKinley, technical analyst, OCT; Mr. C. H. Kimzey, business analyst, OCT; Dr. N. Bhagat, economic analyst, OCT; Dr. W. L. McLaughlin, NBS; Dr. G. J. Vanderbrug, NBS; Mr. Judson C. French; Mr. Stanley D. Rasberry; Dr. John H. Smith; Dr. Jerome Kruger; Dr. H. I. McHenry.,

### *B. Suggestions for comparative analysis*

A retrospective evaluation of the nine areas selected for this study showed considerable variation in the elements for comparison. The primary characteristics selected for each area and related questions were:

*1. Technical quality of proposed projects.*—Are the projects truly representative of generic technology needs? Was there general agreement by experts on selected projects? Do the projects represent new directions and potential break-through achievements? Are the projects sufficiently detailed to be meaningful for estimation of objectives, costs, impacts, duration, skills required, organization, etc.?

*2. Leverage of potential R&D results.*—Are the recommended projects likely to provide a new thrust for proprietary developments? Is the industry or technology sufficiently significant to have a major economic impact? Is there likely to be a meaningful favorable effect on other important industries? Is there a clear relationship between this industry's performance and national productivity, balance of payments and prospects for international trade? Is the industry adequately progressive and able to exploit upgraded generic technology?

*3. Compatible infrastructure of industry.*—Are there in place institutions (universities, trade and professional organizations, independent laboratories, etc.) able to assume the functions of Cooperative Technology Centers? Is there a leadership cadre of industry executive and research people that can be involved productively in a Cooperative Technology Program? Does the industry have a tradition of quality R&D and a broad understanding of its current and future opportunities?

*4. Attitudes of industry representatives.*—Is there a good understanding of CT and a favorable attitude toward the concept? Is there a willingness to work with government in a cooperative mode? Are there reasonable expectations for an industry-government relationship? Does the industry have a tradition of technological risk-

taking? Are there indications of an intention to commit resources to a CTP? Is there a mechanism for continuing the industry-government dialogue?

*5. Feasible level of support required.*—Do the projects involve an investment within the joint funding capabilities of govenment and industry? Is the capital resource in place or does it require a large initial outlay for equipment? Is industry able to carry a reasonable share of the funding required? Can the CTC's be expected to become progressively self-sufficient in the following years?

APPENDIX C

*C. Suggested design factors for cooperative technology program*

Although certain general principles and policies are basic to the Cooperative Technology concept, the design of a Cooperative Technology program for an industry area must be specific to that area. Some of the variables affecting this design are:

1. The nature of the generic R&D projects.
2. The level of financial support and the ratio of industry-government funding.
3. The number of Cooperative Technology Centers to be established and the division of responsibility.
4. The needs of participating companies and of future member companies.
5. The size, quality, and distribution of the existing university research infrastructure.
6. The presence or absence of a strong, representative trade association. If it exists, is it suitable to play a role in the Cooperative Technology Program?
7. Availability of candidate institutions for Cooperative Technology Centers, quality of facilities, research staff and related experience.
8. The prospect of effective industry leadership to launch the Cooperative Technology Program and manage it successfully.
9. Industry attitudes toward government as they will affect the ongoing cooperative relationship and the continuing support of the program.
10. The history of industry-university cooperation in the industry and its current state as a base for further development.
11. The degree to which the industry is accustomed to working with the government.

APPENDIX D

*D. Workshop proceedings and supplemental documents*

(Available individually on request)

1. Workshop Proceedings: Automated Batch Manufacturing
2. Workshop Proceedings: Composite Material
3. Workshop Proceedings: Welding & Joining
4. Workshop Proceedings: Textiles
5. Workshop Proceedings: Powder Metallurgy
6. Workshop Proceedings: Organic Coatings
7. Workshop Proceedings: Semiconductors
8. Workshop Proceedings: Radiation Processing
9. Workshop Proceedings: Corrosion
10. Workshop Proceedings: Adhesives Survey

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[From Science, January 1980]

RESEARCH, INNOVATION, AND UNIVERSITY-INDUSTRY LINKAGES

(By Denis J. Prager and Gilbert S. Omenn)

*Summary.*—Carter Administration actions to enhance basic research and stimulate industrial innovation have focused attention on the importance of formal university-industry cooperative relationships in science and engineering. We have examined the status of, and potential for, university-industry research consortia and research partnerships and the current and prospective roles of the federal government in stimulating such relationships.

Trends in American research and development, technological innovation, and productivity are perceived by many to threaten this country's ability to meet critical domestic challenges and to maintain our international technological and economic leadership. In comparison with the dramatic gains made by a number of other

countries, innovation and productivity in the United States appear not to be faring well. The many factors that may be contributing to this comparative decline include: economic and trade policies; environmental, health, and safety regulations; tax policies and venture capital formation; federal procurement practice; direct federal support of R & D; policies governing patents and information; the regulation of industry stucture and competition; and managerial philosophies and practices affecting R & D (*1*).

One of the many potential avenues to enhance basic research and stimulate industrial innovation examined by the Office of Science and Technology Policy (OSTP) is strengthening the linkages between research and innovation and between the principal institutions involved in these activities—universities and industry, respectively. Of particular interest are university-industry research consortia and research partnership—that is collaborative research relationships governed by a specific, detailed contractual agreement and characterized by joint planning, management, and implementation of a significant, long-term research program of mutual interest and benefit. Over the last several years, the topic of university-industry interaction often has been discussed in the broader contexts of basic research and innovation. However, in order to focus explicity on this subject, OSTP convened a small meeting of university, industry, and goverment representatives (*2*) to obtain their perspectives on the status of, and potential for, formal university-industry research partnerships of these kinds. It is our purpose here to assess the potential for increased numbers of such relationships; enumerate the incentives for, and barriers to, their establishment; cite examples of successful consortia and partnerships; and weigh various options for federal involvement in the initiation and maintenance of such relationships.

*The university-industry connection*

The overall innovation process encompasses a spectrum of activities from basic research to commercial application and marketing. For the innovation process to be productive, the generation of new knowledge and the translation of that knowledge into commercial products and services must be linked. Such linkage depends on close interaction between those who perform basic research and those for whom the results of basic research are the raw materials for product development and commercialization. Because a major share of basic science is done in the universities and colleges, whereas technological development is lodged primarily in industry, stong university-industry relationships can enhance the basic research-innovation linkage (*3*). Historically academia and industry had a productive relationship, each helping to support the other's mission. However, the links between unversities and industries weakened in the two decades following World War II, approaching their lowest point in the early 1970's. Smith and Karlesky (*4*, p. 62) have identified three principal factors underlying this decline.

1. The separation of academic research from perceived industrial needs. This separation came as a result of the increasing role of the government in science and technology, stimulated first by World War II and then by Sputnik. With the federal government supplying the major portion of available research funds, universities had much less incentive to establish, or strengthen, ties with industrial firms.

2. The decreased interest among unversity graduates in industrial research careers. With the availability of federal funds for academic research and education, more and more graduates eschewed industrial careers for faculty appointments, and graduate training programs became oriented toward careers in academic research. Industrial research was judged to be too applied and industrial research positions viewed as second-rate.

3. Industry's diminishing role in basic research. The industrial share of basic research spending declined steadily between 1955 and 1972, and the proportion of in-house R & D budgets allocated to basic research dropped dramatically after 1966 (*5*, *6*). Since the key to effective interaction between universities and industry was scientist-to-scientist contact on research matters of common interest, the gradual decline in industrially performed basic research decreased such contacts and impeded university-industry relations.

As a result of these and other factors, there has been a marked decline in the linkages between academia and industry. This decline may be a contributing factor to the erosion of the innovation process because it impedes the kind of two-way communication that influences the direction of research and facilitated its practical application. Such separation also complicates research that falls between pure, basic science and applied R & D. This research is conducted with an eye on ultimate application and is critical for major technical advances in many fields.

*Incentives for enhancing the university-industry connection*

Universities have a number of motivations for reassessing their ties with industry. There is a growing research interest in solving critical domestic problems and a renewed appreciation for the role of industry in such problem-solving. However, the primary motivations are more pragmatic. Academia finds itself being squeezed by its major research sponsor—the federal government. Competition for federal research funds has dramatically increased as inflation has eroded the purchasing power of the research dollar and increasing numbers of young scientists have sought support for their work. At the same time, government regulations related to scientific and financial accountability, human and animal experimentation, biohazards, and affirmative action have reduced the efficiency, flexibility, and independence of the academic scientist. This situation is aggravated by declining student enrollments and by decreasing employment opportunities in academic and government research centers. For these reasons, university faculty and administrators are beginning to look to industry as a source of research support, as a potential employer of advanced degree graduates, as a source of part-time faculty, and as a focus for major continuing education programs. Perceived benefits for universities include the potential for long-term research support less entangled in red tape; help from industry in making new knowledge and technology commercially useful; broader educational experience, industrial exposure, dissertation topics, and potential employment opportunities for students; and stimulation of university faculty through interaction with industrial scientists and engineers and through access to specialized industrial equipment.

Industry's incentives are equally compelling. American industry is facing stiffened competition at home and growing challenges abroad. New science-based technology is required by industry not only to meet these challenges but also to satisfy environmental, health, safety, and efficacy regulations economically. Academic institutions, with their broad array of disciplinary capabilities and research interests, represent a scientific resource that can enhance industrial research efforts (*3; 4,* p. 65). Potential benefits for industry include additional sources of ideas, knowledge, and technology on which to base potential new products and processes; ability to draw upon competent scientists from around the country without expanding in-house capabilities; high benefit to cost ratio when compared to building an in-house research unit; source of potential research employees sympathetic to industry needs; and stimulation of industrial scientists and engineers.

The country as a whole would benefit from improved substantive relations between universities and industry. Innovation should be significantly accelerated by reestablishing the role of market motivation in stimulating research and in enhancing the linkage between the development and application of new knowledge. Furthermore, the strengthening of both the academic and industrial sectors would enhance the quality and relevance of research, the stability and robustness of the research enterprise, the breadth and problem-solving capabilities of university graduates, and the competitiveness of the U.S. industrial sector.

*Barriers to enhancing the university-industry connection*

Academic institutions are in the business of education and training. Therefore, university research is necessarily oriented toward the educational experience and the extension of fundamental knowledge. University research seldom is directed at new commercial products or processes, although it may be the basis of innovation. The emphasis is basic science and engineering, not development and commercialization. The time frame for obtaining and reporting results is long-term; freedom of communication and publication is at the heart of the academic research process; and intellectual independence is paramount. Industrial research, in contrast, normally looks to development and commercialization of new and improved products, processes, and services. Because competitive edge is critical to the success of a commercial venture, patents are important and the results of research often are proprietary and may not be published (*4,* p. 65; 7).

There are also institutional barriers. Management philosophies, for example, differ greatly. Industry is responsible to its stockholders; its bottom line is financial viability and profits; the goal of its research is new, improved products. Industry research is run by upper management in direct support of the company's interests; management sets objectives and directs the research. Universities present themselves to "the public"; their bottom line is represented by number and quality of students and research productivity. University research is conceived and conducted by researchers: the university provides facilities and a supportive environment.

Industrial firms face a further dilemma when considering the support of university research: in-house versus extramural research. Corporate managers must be able

to explain why they chose to commit research funds to an outside institution rather than build or maintain an in-house research capability which the company could more easily control and which might appear to be more cost-effective. Under what conditions is such an external commitment justified? Three were suggested by the participants in our meeting (2): (i) when outside assistance is required to maintain leadership in an existing product line, (ii) when the company needs "cutting edge" science to develop new leads in an existing line, and (iii) when management wishes to pursue research in wholly new product lines.

Another barrier to establishment of major university-industry research partnerships is uncertainty. The stakes are high and so are the risks. Time and dollar costs are significant and the magnitude of the potential payback is highly speculative. Also, the time period may exceed the tenure of the scientists and managers who thought the partnership was such a good idea. Both universities and industrial firms are basically conservative. Universities are reluctant to enter into long-term, detailed agreements with industry for fear of compromising academic freedom and jeopardizing federal funding of related research (8). Industries respond to increased governmental regulations and changing economic conditions by focusing their limited resources on "defensive research," that is, research resulting in incremental changes to existing products, process innovation to increase productivity and decrease production costs and time, and development of cost-effective ways to meet environmental, health, and safety regulations.

These relatively tangible differences between the academic and industrial sectors are magnified by attitudes that exaggerate the differences, inhibit meaningful communication, and impede attempts to form cooperative arrangements. Academicians often disdain the profit orientation and distrust the motives of industry. Some seem to believe that all industrial research is applied product development; that the competence of industrial researchers and the quality of their research is inferior; and that university-industry interaction means industry direction of university research, applied research only, lower standards of quality, no publications, only proprietary work, and no real interaction (that is, industry supplies the money, university supplies the brains). Conversely, university research is viewed by industry as ivory-tower with little thought to applicability and too much reliance on the cumbersome publications process. Industry often finds university graduates to be too theoretical and unable to make the transition to the more applied orientation of industrial research. Such attitudes are the most difficult barriers to overcome and constitute the most significant challenge to those who believe that increased numbers of formal university-industry research relationships are desirable.

TABLE 1.—*Types of university-industry relationships (4, pp. 65-69; 11)*

*Corporate contributions to university*

Undirected corporate gifts to university fund

Capital contributions: gifts to specific departments, centers, or laboratories for construction, renovation, equipment

Industrial fellowship: contributions to specific departments, centers, laboratories as fellowships for graduate students

*Procurement of services*

By university from industry: prototype development, fabrication, testing; on-the-job training and experience for students; thesis topics and advisers; specialized training

By industry from university: education and training of employees (degree programs, specialized training, continuing education); contract research and testing; consulting services on specific, technical, management problems

Industrial associates: single university; usually multiple companies; industry pays fee to university to have access to total resources of university

*Cooperative research*

Cooperative research projects: direct cooperation between university and industry scientists on project of mutual interest; usually basic, nonproprietary research. No money changes hands; each sector pays salaries of own scientists. May involve temporary transfers of personnel for conduct of research

Cooperative research programs: industry support of portion of university research project (balance paid by university, private foundation, government); results of special interest to company; variable amount of actual interaction

Research consortia: single university, multiple companies; basic and applied research on generic problem of special interest to entire industry; industry receives special reports, briefings, and access to facilities, for example

*Research partnerships*

Joint planning, implementation, evaluation of significant, long-term research program of mutual interest and benefit; specific, detailed, contractual arrangement governing relationship; both parties contribute substantively to research enterprise

*Types of university-industry relationships*

In spite of these substantial barriers, many universities and industrial firms have established relationships which, to differing degrees, meet the diverse objective of the two parties. In Table 1 we show relationships ranging from undirected financial gifts to significant research partnerships. In fact, a whole spectrum of university-industry interactions and relationships is possible depending on the goals and objectives of the respective organizations and their institutional characteristics. Relevant factors include: the size, structure, and profitability of the industry, the nature of its business, and the progressiveness of its research program; and the type, size, and financial health of the university, the relative size and stature of its science and engineering programs, and the orientation of its research and researchers. External factors such as geographic proximity, the location of university alumni in key industrial positions, and migration of university faculty to industry and vice versa may be very influential.

Several examples of existing relationships illustrate the diversity of potential interactions. The California Institute of Technology (Caltech) has developed several industrial associates programs. These relationships have worked out very well for both the university and the industrial firms involved. Top university scientists regularly visit industries to learn of their problems, explore scientific and technical approaches to solving those problems, and lay the groundwork for potential cooperative arrangements. This type of regular interaction, which raises the consciousness of each party with regard to the problems and capabilities of the other, is relatively common among high-technology universities. Such universities have strong science and engineering faculties, have spawned many high-technology firms within close geographic proximity, and have maintained close ties with industry.

Bell Laboratories maintains a large number of individual scientific and technical arrangements with universities around the country. These are low visibility, scientist-to-scientist, or engineer-to-engineer interactions of peers working on topics of common interest. The research is generally basic science and engineering and not proprietary in nature; publications are common and are encouraged. This kind of peer collaboration is only possible when the industrial partner has a significant, progressive in-house research capability employing accomplished scientists and engineers with acceptable academic credentials. Such capabilities are characteristic of only a few major corporations.

Research consortia provide an opportunity for a single university to relate to a number of companies in an area of science and engineering in which the university has an outstanding capability and the companies share a need for research. Member companies pay a fee to support university research of generic interest to an industry; all member companies share the results of the research. Examples of such consortia include the Carnegie-Mellon Processing Research Institute, the University of Delaware Catalysis Center, the North Carolina State Furniture Institute, the Cornell Injection Molding Project, and the MIT-Industry Polymer Processing Program.

The MIT program involves 12 member companies who pay $29,000 to $100,000 per year depending on their size and volume. A total of $560,000 supports approximately 25 projects in such areas as friction and wear of polymers, powder coating techniques, biocompatible materials, injection molding of ceramics and polymers, and nondestructive testing of composites. Most of the funds go to support graduate students. The program was started with seed funds provided through the Experimental R & D Incentives Program of the National Science Foundation (NSF). MIT staff meet often with company representatives to identify industry problems and define research needs. MIT selects the projects to be supported and provides all member companies with briefings and reports. Projects can be characterized generally as applied R & D on problems generic to an industry and one step ahead of the current state of the art. The university owns all patents and can license member or non-member companies. Royalties earned by MIT are shared with member companies on the basis of their yearly assessments. Publications are encouraged. MIT views this program as an excellent learning experience for students; a stimulus for faculty and students to innovate; a means of rapid technology transfer from research to application; a stimulus for broader university-industry interaction; and a means of opening up new disciplines. Industry benefits from new ideas and processes; a source of competent manpower at relatively low cost; timely assessment of

current industrial practices; and having a basis for comparative evaluations of internal R & D.

The relationship most often cited as a true partnership is that between Harvard and Monsanto. Built on personal interactions spanning some 16 years, a research partnership has been established in which both parties contribute substantively to progress in a promising basic science field—the biochemistry and biology of organogenesis. As part of its long-range planning, Monsanto's management was aware of the commercial possibilities of biological research and decided to commit substantial resources to Harvard over a period of 10 to 20 years to explore and expand the field and to allow Monsanto to obtain expertise in it.

The resulting partnership is governed by a charter agreement that serves as an umbrella for a number of more specific agreements covering individual programs. Recognizing the long-term nature of fundamental research in complex systems, the agreement spans 12 years. Monsanto funds, which are used at the discretion of the university to further any specific scientific aims within the purview of the charter agreement, support Harvard personnel from several disciplines and departments. The two parties contribute equally but in different forms to the partnership. Harvard provides the conceptual scientific framework, identifies capable scientists, provides training, and controls relevant research at both Harvard and Monsanto during the research phase. Monsanto helps identify research needs, provides critical starting materials beyond the ability of Harvard to produce or buy, provides unusual and exotic analytical capabilities, and controls the development phase, providing expertise in technological innovation, development, and marketing.

The disposition of potential patents and publications is spelled out in the charter agreement. Harvard can receive royalties from either Harvard or Monsanto patents; but, in return, Harvard has waived royalties on initial sales. Monsanto controls its own inventions and receives exclusive license to all Harvard inventions in the area of cooperation for a specific period of time provided that they are progressing toward commercialization. There is no restriction on publication by either partner of its own results; the only obligation is that the other partner be informed prior to publication. The partners are in no way constrained from disclosing their own data but are constrained from disclosing information gained from the other. An outside public board advises on nonscientific policy issues.

Several features characterize this relationship. The focus of the partnership is a major new area of science of uncertain future applicability to Monsanto. The industrial partner is a substantial firm with progressive management and a highly developed research program. They do not have and do not wish to develop basic research competence in the area of cooperation. The university partner is a large, stable, productive basic research group with high interest in developing the scientific area of cooperation. The partnership evolved from long-standing personal relations between the principals.

Potentially interested corporations and university research groups that might meet the descriptions of the industrial and academic partners given above seem to us to be observing the Monsanto-Harvard experiment and examining their own opportunities with caution. We hope that such joint ventures will generate new approaches to linking basic research and innovation.

*Current Federal activities*

The government already has had a significant part in bringing the academic and private sectors together. The following examples illustrate several different kinds of federal involvement.

The National Aeronautics and Space Administration (NASA) and the Department of Defense, through their major technology development and procurement programs have stimulated the formation of research consortia to direct their collective capabilities toward the solution of specific technical problems. The Department of Energy has stimulated university-industry-government cooperation in R & D related to specific energy technologies.

The Department of Commerce (DOC) enlists the aid of universities in facilitating the introduction and application of technologies designed to improve the competitiveness of industries in the international marketplace. DOC funds a university to analyze a trade-impacted industry's structure and operations and its product development, manufacturing, and marketing methods, and to identify specific weaknesses. Working with a panel of technology-oriented business experts, the university then formulates a detailed implementation plan which is presented to representatives of the industry for their consideration. To date, this process has been initiated for the steel, footwear, stainless steel flatware, industrial fasteners, consumers electronics, and men's and women's apparel industries.

The NSF supports university-industry centers, university-industry research projects, and small business innovation. Through the university-industry centers the NSF encourages institutional arrangements between the university and industrial communities to stimulate scientific research and technological innovation. NSF funding of these centers begins at 100 percent during start-up and phases out as industrial membership increases. At the MIT center, for example, industry support has risen from $50,000 in 1973 to more than $500,000 in 1979, when industrial partners paid the full cost of center's program.

The NSF also supports cooperative research projects carried out jointly by academic and industrial researchers in several fields of science and engineering. The projects are investigator-initiated, focusing on fundamental scientific questions. Proposals are reviewed for scientific merit via the Foundation's regular peer review process. Funding for the university is partly from the Divisions whose fields of research are involved, partly from a special account for this purposes. This program is attracting interest from a variety of institutions. For example, Bell Laboratories is working with Lehigh University on thermal convection in cavities; several computer firms are working with Caltech on design of silicon structures; Eastman Kodak and Clarkson College of Technology are investigating crystal formation in surfactant solutions; and Artisan Industries and the University of Houston are studying the fundamental mechanics of a filtration process.

The Small Business Innovation Program at NSF funds creative, technologically high-risk, potentially high payoff research in broad topic areas identified by NSF as having high national priority. Examples of such areas include advanced production and manufacturing processes, alternative biological sources of materials, measurement and advanced instrumentation, chemical threats to man and the environment, and deep mineral resources. NSF funds are used as "preventure capital" to conduct feasibility research on the innovative idea to attract private support. In some cases, university scientists and engineers serve as consultants to small businesses participating in this program.

Facilitative federal programs such as these are proving successful and gaining acceptance as examples of the most desirable federal role in bringing about increased university-industry interaction. The government serves a stimulative short-term role, minimizing taxpayers' cost.

*Promoting university-industry linkages*

In spite of these successes, opinions are divided over the proper Federal role in the initiation and maintenance of formal university-industry research relationships. Some are convinced that the government has no role and should allow universities and industry to develop relationships as appropriate. These people argue that government participation might limit the flexibility or diversity of industry-university arrangements. Others visualize a range of Federal roles. At a minimum, they see the government contributing by attempting to remove disincentives to research and innovation in general. At the next level of involvement, the Government could identify problems requiring research, help identify potiential partners, and facilitate negotiations. A more active role would involve the government's providing start-up funds. Finally, the government could be a third partner, sharing costs with the industry and university. In this case, too large a government role could lead to Federal interventions in activities that should be the responsibility of business and industry.

On the basis of this review of the status of, and potential for, formal university-industry research relationships, several means of promoting the establishment of university-industry linkages can be suggested. Many of these were addressed in the President's Industrial Innovation Initiatives announced by the White House on 31 October 1979 (*9*).

*Improved communication.*—There is a need to accelerate contacts between university administrators and scientists and their industrial counterparts. The objectives of these contacts are to erase preconceptions; increase understanding of goals, management philosophies, and research orientations; and lay the groundwork for improved relations and potential research cooperation. The government can facilitate this process in some cases by identifying individual and institutional barriers to improved communication and by instituting specific programs (information exchange, personnel exchanges, and conferences, for example) designed to stimulate contacts and substantive interaction. Such activities should attempt to remove interinstitutional impediments and focus on scientific matters of mutual interest. Successful relationships depend on joint efforts of individuals with sufficiently strong interest and competence in a scientific question or engineering problem that institutional barriers are surmounted.

*Direct Federal support of research.*—Representatives of both the academic and industrial sections have stated strong support for the use of Federal grants as seed money to facilitate initiation of new university-industry relationships. Such grants would enhance industrial support of university research programs meeting specific criteria including demonstrable university-industry cooperation. The NSF program of cooperative research projects described above is a highly successful example of such an approach. The President has announced his intention to provide NSF with $20 million of new funds in Fiscal Year 1981 to expand this program. Furthermore, NSF will work with the Department of Defense, Department of Energy, Environmental Protection Agency, and NASA in fiscal year 1980, and with other agencies in subsequent years, to initiate such university-industry cooperative research programs. Ultimately, an aggregate program funding level of $150 million is envisioned.

In addition, the Administration intends to establish nonprofit centers—at universities or other private-sector sites—to develop and transfer generic technologies. Each of the centers will be targeted on a technology that is used in several industrial sectors and has the potential for significant technological upgrading. Each center will be jointly financed by industry and government, with the industry share increasing each year. Four centers will be established in fiscal year 1981 at a cost of $6 million to $8 million. Three will be sponsored by the DOC and one by the NSF.

*Joint Federal and industry support of basic research.*—The Federal Government and the automotive industry are planning a jointly sponsored program of basic research aimed at improving fundamental automotive technology (*10*). The program will focus on nonproprietary, generic research of interest to the entire industry, developing new knowledge in such fields as thermodynamics, structures, friction and wear, and combustion. The Department of Justice has indicated that a basic research program of this kind is consistent with antitrust law. A large portion of the research will be carried out in university laboratories under joint government-industry funding; improved university-industry relations are an important anticipated benefit. This program is seen as a model for similar efforts in other industrial sectors that could benefit from increased support and conduct of reasearch designed to lay the technology base for new generations of products and processes. Efforts are currently under way to identify additional research areas to be the focus of such potential joint efforts.

*Tax incentives.*—Tax credits have been suggested as a way to encourage industry to increase its support of research, including research performed by university scientists. Those who argue for such credits stress the importance of R & D as a factor in economic growth, the more favorable tax treatment of R & D investments in certain foreign countries., and the desirability of increased private sector investment in R & D. However, Canada's use of tax credits has not produced the results expected; because research is the "cheapest" end of the innovation process, incentives at the later stages of the innovation process may be more effective. The Administration has agreed to examine tax policies affecting innovation when determining the overall fiscal policy for 1981.

*Antitrust considerations.*—Many industrial leaders perceive current antitrust laws to discourage or prohibit firms from joining together in the support of research programs of common interest. They seek a change in, or clarification of, current antitrust statutes to permit, or even encourage, competing firms to cooperate in the funding of generic research. The automotive research program described above may provide a precedent for such clarification.

Antitrust laws play a specific role in promoting innovation. Vigorous enforcement of these laws spurs competition and the pressure of competition is a stimulus to the development of innovations that provide a competitive edge. However, antitrust laws are often perceived to prevent cooperative activity among competing industrial firms even in circumstances where such activity would foster innovation without harming competition. Two actions have been taken that will clarify antitrust policy and should spur more cooperative research activity by industry. The Department of Justice will prepare a guide to clarify its position on collaboration among firms in R & D, and the Attorney General, the Chairman of the Federal Trade Commission, and the Secretary of Commerce will initiate discussions with industry about innovation, antitrust policy formulation, and enforcement.

*Patents.*—Patent laws are seen as barriers to cooperation between the private and public sectors. Both industry and university representatives would like federal agencies to change their interpretation of current patent law so that exclusive licensing by industry of inventions discovered under government support would be possible. Such changes would provide an incentive for innovation by academic and industrial scientists and engineers. As part of the Administration's innovation ini-

tiatives, legislation will be sought to establish a uniform government patent policy. Title to the patent will be retained by the government, but the contractor will obtain exclusive licenses in fields of use that he specifies and in which he agrees to commercialize the invention. There will be an exception where the government determines that such a license would be inconsistent with either the agency mission or the public interest. The government would license in all fields of use other than those claimed by the contractor. The government would retain march-in rights that could be exercised in the event that the licensee did not develop the patent. The Administration also supports the retention of patent ownership by small businesses and universities, the prime thrust of legislation now in Congress.

*Regulatory reforms.*—Both industry and university spokesmen have urged the Administration and Congress to require federal agencies to assess the impact of environmental, health and safety, and accounting regulations on research and innovation. As part of his extensive regulatory reform program, the President has directed federal regulatory agencies to respond to these criticisms while meeting their regulatory responsibilities. Performance standards will be substituted for design and specification standards wherever possible; 5-year forecast of regulatory priorities and concerns will be prepared to facilitate improved R & D planning by industry; and agencies responsible for reviewing product safety and efficacy will, to the extent possible, expedite clearance reviews of products that are the most innovative or have exceptional social benefits.

*Conclusion*

The time appears to be ripe for major improvements in university-industry relationships in science and engineering. Although substantial institutional and attitudinal barriers to such relationships exist, the potential benefits are sufficiently compelling to engender confidence that those barriers can be surmounted. The federal government can play a facilitative role in fostering university-industry cooperation primarily by providing incentives and removing disincentives to such interaction. Several elements of the President's industrial innovation initiatives will indeed have that effect. However, strengthening university-industry linkages—and thus enhancing the research-innovation process—will result principally from specific initiatives taken by individual universities and companies. Ultimately, progress in this endeavor will depend on substantive interaction among academic and industrial scientists and engineers whose common interest in solving specific scientific and technical problems overcomes the attitudinal and institutional barriers to university-industry cooperation.

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2. Held on 19 July 1979, the meeting included M. L. Goldberger, California Institute of Technology; J. E. Goldman, Xerox Corporation; N. B. Hannay, Bell Laboratories; P. J. Lucchesi, Exxon Research & Engineering; G. Place, Procter & Gamble; N. P. Suh, Massachusetts Institute of Technology; L. Thomas, Memorial Sloan-Kettering Cancer Center; M. C. Throdahl, Monsanto; B. L. Vallee, Harvard Medical School; F. Press, G. S. Omenn, and D. J. Prager, Office of Science and Technology Policy; T. Schell, Department of Commerce; and J. Sanderson, National Science Foundation.

3. E. E. David, Jr., *Science* **203,** 837 (1979).

4. B. L. R. Smith and J. J. Karlesky, *The State of Academic Science: The Universities in the Nation's Research Effort* (Change Magazine Press, New York, 1977), p. **62.**

5. *National Patterns of R & D Resources: Funds and Manpower in the United States 1953-1976* (National Science Foundation, NSF 76-310, Washington, D.C., 1976).

6. *Support of Basic Research by Industry* (Industrial Research Institute Research Corporation, St. Louis, 1978).

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8. Several university scientists have expressed their perception that federal agencies are reluctant to commit scarce federal funds to a research program receiving significant industry support (they already have so much). Also, there is the problem of peer review—the need for federal agency reviewers to have access to all relevant information, some of which might be proprietary information developed under research supported by industry.

9. The President's Industrial Innovation Initiatives, Fact Sheet, Office of the White House Press Secretary, Washington, D.C., 31 October 1979.
10. P. M. Smith, testimony before the Subcommittee on Transportation, Aviation, and Communications of the Committee on Science and Technology (U.S. House of Representatives, Washington, D.C., 12 July 1979).
11. R. Roy, *Science* 178, 955 (1972); P. C. White, *Res. Manage.* (January 1973), pp. 10–15; R. A. Swalin, *ibid.* (May 1976), pp. 25–27.
12. We gratefully acknowledge the encouragement of Frank Press and the assistance of Philip Smith and Richard Meserve (all with OSTP) in the preparation of this article, especially in the description of the innovation initiatives undertaken by the Administration.

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U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
*Washington, D.C., November 27, 1979.*

Dr. JORDAN J. BARUCH,
*Assistant Secretary for Science and Technology,*
*Department of Commerce, Washington, D.C.*

DEAR DR. BARUCH: Following up on your testimony before my Subcommittee on S. 1250, the National Technology Innovation Act, I should like to request that the following information be made available for review by the Subcommittee:

1. A copy of the study conducted by the Industrial Research Institute for your office, identifying and analyzing industrial interest in the proposed Cooperative Technology Program;

2. Status and findings of the Department of Commerce's study on the Cooperative Technology Program, including the proposed generic technology centers. Specifically, information on (a) how the centers would operate, (b) how priorities would be established and what criteria would be used, (c) the role education would play, and (d) the role advisory services would play; and

3. Background material that serves to explain and support the proposals made by the President to establish (a) a Center for Technology Utilization in NTIS; (b) Foreign Technology Utilization programs; (c) Corporations for Innovation Development; and (d) a Presidential Award for Technology Innovation.

I would appreciate your furnishing this material as soon as possible. With every good wish.

Sincerely,

ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science,*
*Technology, and Space.*

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U.S. DEPARTMENT OF COMMERCE,
ASSISTANT SECRETARY FOR SCIENCE AND TECHNOLOGY,
*Washington, D.C., January 22, 1980.*

Hon. ADLAI E. STEVENSON,
*Chairman, Subcommittee on Science, Technology, and Space,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR STEVENSON: Following my testimony on S 1250, the National Technology Innovation Act, you asked for additional information. Enclosed with this letter is much of the information you have requested. In answer to your specific questions:

1. A copy of the Industrial Research Institute study has already been forwarded to your office along with the edited version of the transcript of the hearings.

2. Enclosed you will find a copy of a draft of a Final Report of the Cooperative Technology Program Study. Also the specific information requested regarding Center operation and priorities as well as the role of education and advisory services is discussed in a separate enclosure.

3. Another enclosure discusses the currently envisioned methods of operations of the new Presidential Initiatives concerning the Center for the Utilization of Federal Technology; the Foreign Technology Utilization Program; the Corporations for Innovation Development and the Presidential Award for Technology Innovation.

Supporting material which discusses prior structure and experience with other entities which resemble the proposed CID's is being assembled; but rather than delay your receipt of this material, the other documents will be forwarded separately as soon as possible.

As you may recognize, many of the initiatives announced by President Carter with regard to Industrial Innovation appeared either directly or in somewhat modified form in the reports of the Advisory Committee on Industrial Innovation. The Final Report of these committees has now been issued. I enclose three copies, but please contact my office if you would like additional copies.

Sincerely,

JORDAN J. BARUCH.

Enclosures.

U.S. DEPARTMENT OF COMMERCE, COOPERATIVE TECHNOLOGY PROGRAM

*Disclaimer.*—This is an interim report on a study of the desirability and feasibility of a program of cooperative technology. The findings of this report are preliminary and are undergoing change. The contents of this report do not represent official policy or conclusions of the Department of Commerce. Rather they are meant to stimulate discussion.

For further information please contact Frederick L. Haynes, Director, Office of Cooperative Technology (telephone 301-921-2446).

This report should not be quoted as reproducing in whole or in part without including this disclaimer.

EXECUTIVE SUMMARY

This report was requested by OMB as a further explanation of the concept of a Cooperative Technology Program (CTP). Concurrent with the review of the draft version of this report by Office of Management and Budget (OMB), the concept of a Cooperative Technology Program was included as a recommendation and subsequently approved by President Carter as part of the Domestic Policy Review on Industrial Innovation. Being a concept paper, this report does not contain a specific implementation plan or detailed answers to the many questions which have arisen and will continue to arise now that the program is approved. Actual implementation may change some of the ideas or methods described in this report and will certainly require extensive elaboration of the ideas. Other questions and problems will be impossible to answer accurately in the abstract but must be solved on a case by case basis. The report addresses, and is organized around the following eight specific questions posed by OMB.

*1. Document and analyze the state of technology and R&D for selected industries—through public hearings and research*

The Industrial Research Institute Research Corporation (IRI/RC) was retained to survey nine industrial technology areas to determine the willingness of companies to work cooperatively with each other and with government, to identify appropriate R&D projects, and to estimate the potential costs and benefits of a cooperative program.[1]

Through extensive research by the principal investigators, personal contacts with more than 250 industrialists and university research specialists, and through public workshops on each industry, there was general agreement by industry favoring the CTP concept. Moreover, industry would be prepared to make substantial, long-term commitments to the CTP if DoC could alleviate basic concerns about antitrust and Federal Trade Commission (FTC) restrictions, protection of proprietary rights, size and complexity of management organization, exact nature of Government involvement, etc. The program design discussed in Chapter III attempts to respond to these concerns to the point where a CTP can be initiated with good prospects of industry participation and support.

As we expected, the state of technology varies widely among the industries selected, as does the level of R. & D. activity. By examining each industry or technology as a whole, it was possible to identify underlying development problems associated with the technology which often can only be perceived or attacked collectively. As a result, in most of the case studies, several generic technology projects have been identified which generate major productivity advances contributing to a growing, competitive, and noninflationary economy (See Appendices 1-10).

While study of existing industries can identify compelling R. & D. needs which could benefit greatly from intra-industry cooperation, a study of generic technologies can identify latent technologies yet to be invented (or those which are in use

[1] The industrial technology areas are: Industrial Radiation Processing; Powder Metallurgy; Automated Batch Manufacturing; Organic Coatings; Semiconductor Electronics; Textiles; Welding and Joining; Corrosion Treatment; Composite Materials. In addition, discussions are continuing with key people in the food processing, graphic arts, construction, and cement industries; workshops are planned for the near future.

in one industry but are candidates for application in other industries) or promising new industries which do not yet exist. A collective approach is designed to provide not only the resources and organization to attack problems already identified in an existing industry, but also to broaden the perception of need and opportunity and thus to encourage the creation of new industries, technologies and applications. Such initiatives are rarely possible within the compartmented, competitive atmosphere of existing industries, particularly those which are mature and growing slowly.

*2. Survey Federal and State programs which provide financial and technological business assistance for each selected industrial technology area*

Chapter II describes the surveyed programs. With the exception of trade-impacted industries which have specific Federal and State programs for economic adjustment assistance, we found no coordinated or focused programs to assist the industries selected.

There are, however, broad programs designed to help businesses in general. They range from the Small Business Administration's Venture Capital Investment program and the National Science Foundation's small business efforts, to the Department of Defense manufacturing technology development efforts. The latter program relates broadly to automated batch manufacturing—but only as it pertains to defense-related industries.

There are also 31 State Productivity Centers which on a regional basis attempt to enhance the productivity growth of manufacturing, distribution, and retail establishments. Again, these do not concentrate on the case studies we have selected.

When taken together, however, it is possible that some initial overlap and marginal duplication may become evident between the CTP and other Federal and State programs. At this point in the CTP development, the degree of overlap cannot be anticipated.

Consequently, as Cooperative Technology Centers (CTC) are identified and created, we will coordinate with other economic and technological assistance programs as appropriate.

*3. Review past Federal and State cooperative technology programs and those of other countries*

Within the U.S., there have been long-standing cooperative arrangements in areas where the government was the sole or major market for the goods and services produced (e.g., national defense, environment, space and energy). However, where the private commercial sector is concerned we found that, with the exception of certain Department of Agriculture programs, National Science Foundation (NSF) experimental programs, and a few tentative starts by earlier administrations, there are no operating programs similar to those proposed for a Cooperative Technology Program.

In contrast, our trading partners, particularly the advanced industrialized countries, maintain long-standing formal and informal cooperative programs to enhance the technological competitiveness of the goods and services produced by their industrial base. While some of their programs predate World War II, most have evolved since then, many initiated with direct U.S. Government funding. Even today, our foreign assistance programs and military co-production agreements act as significant aids in developing and diffusing advanced technologies to our existing and potential competitors.

As foreign initiatives have matured, cooperative technology programs have become embodied in well-coordinated industrial and innovation policies. These embrace not only the cooperative R&D efforts themselves, but also a broad range of business incentives such as: rapid depreciation, low-cost loans, liberal grants, tax rebates, export assistance, and a relative absence of antitrust concerns, Because these cooperative programs are interwoven into a broad matrix of mutually supporting industrial and innovation policies and incentives, assessments of effectiveness of the cooperative efforts have been rarely attempted and difficult to perform. Nonetheless, based on our research, we believe cooperative R&D that foreign programs have contributed to our partners' superior economic growth rate and competitive challenges to U.S. industry.

*4. Analyze all Federal mechanisms which could be employed in theory to resolve industry's technological problems*

This is the subject of the Domestic Policy Review of Industrial Innovation. A copy of the press release explaining the various actions which were approved by the President is appended. (See Appendix 22.)

*5. If a cooperative technology program is still justified, define appropriate goals and objectives*

There is no doubt that industry is interested in the Cooperative Technology program and can be expected to make substantial contributions towards its success.

The goal of the CT program is to spur the generation and use of scientific and technical knowledge which is essential for industrial development by acting as a catalyst to:

*(a) Aggregate resources.*—Pool Government and industry resources to accomplish projects which are not within the resources of any one company due to size, risk, time-frame, etc.

*(b) Create a planning perspective*—Foster a basic awareness which over time will help: (1) To raise the technological level of established industries; (2) to stimulate new technologies; (3) to diffuse existing technologies within an industry and from one industry to another; and (4) ultimately, to create new industries. If successful these activities will contribute, from the base up, to meeting major economic and societal goals such as:

Better control of inflation through the early development and diffusion of productivity-enhancing technologies.

Strengthen the balance of trade by upgrading technological content of our goods and services, thus making them more competitive internationally.

Conserve natural resources by developing process technologies which minimize the use of materials, energy, and other resources in the production of goods and services.

Increase employment by stimulating new, high technology companies which are major generators of new job and skill requirements.

Alleviate regional dislocation by strengthening the technological base of mature, regionally concentrated industries.

Improve working conditions and protect the environment by developing improved process technologies.

*6. Design a cooperative technology program*

To achieve the goal and objectives set forth above, the Cooperative Technology Program proposal includes the following design criteria:

The Program should have sufficient flexibility to meet the specific needs of each industrial area it serves.

The Program should fit within the existing infrastructure of policy, laws and regulations.

The Program should accommodate the needs of growth in both mature and emerging industries.

The Program should foster the introduction of technologies so as to enhance job creation.

The Program will require a level of industrial and government commitment sufficient to ensure a high probability of success.

Using the aforementioned criteria—and drawing the best from the worldwide inventory of formal and informal government, industry, university and labor cooperative arrangements, a preliminary design (Chapter III) has been developed which meets the needs and concerns of industry, yet is flexible enough to continue to evolve as experience is gained.

The program design defines the roles of two major participants, Government and the private sector. The Government role is that of arrangement making. The private sector role is the management and execution of technical programs. Both share the funding requirements.

The primary Government mechanism to perform this role is the Office of Cooperative Technology (OCT).

The Cooperative Technology Center (CTC), a key mechanism through which industry participates in the CTP, is designed to be a nonprofit, jointly supported organization which will carry out the research, and also provide for rapid diffusion of the technology developed through specific activities such as: consulting and technical services; information services and labor and management education. Results will be disseminated to other user industries through a technology transfer and utilization function, and emphasis will be placed on identifying technology barriers in order to improve strategic planning.

The orchestration of these public and private mechanisms can be best described by the following brief scenario:

An industry recognizes and agrees that there are urgent, common technological barriers beyond the capabilities of individual firms to surmount. Moreover, they

foresee a high probability of success if they could work together and with government in a cooperative mode.

After the Department of Commerce confirms the above situation and determines a strong public stake in the outcome, the industry selects one or more organizations (universities and/or private labs) to become focal points for the cooperation. Firms jointly form a nonprofit corporation(s) as a Cooperative Technology Center(s), embodying the structure and functions of Figure 2, page 43.

A Cooperative Technology Program for a specific field of industrial technology (e.g., semiconductor electronics and CAD-CAM) could involve several competing Centers. Such competition would be valuable in maintaining the quality and vitality of a program. A certain degree of technological specialization, however, might be appropriate for certain centers to utilize existing experience and resources. Government would fund the start-up operations of designated Centers, but after 3-5 years would gradually refocus its support to specific projects which would be unlikely to receive adequate funding from individual companies (e.g., advanced research, exploratory development, development of easily copied technologies, work on technologies which might benefit others more than an individual company, etc.). Industry would fund a share of all projects, but would especially support the stability of the center as an ongoing organization (i.e., its core staff, equipment replacement, leasing costs, etc.). Such industrial funding would be justifiable in returning more in tangible benefits than the cost to member firms (e.g., market protection, maintenance of data bases, information and consulting services, training courses which win cooperation of workers in accepting new technology, research which seeks solutions to environmental, safety and operating problems, etc.)

A survey of successful programs of other nations highlights the importance of the features of the prospective Centers. Governments throughout the world have now accepted the philosophy of joint funding with industry of specific projects. Experience also shows it is important for a Center to:

Identify with a specific field of industrial technology and have recognized in-house capability for R&D so that expertise and knowledge growth are cumulative on an existing base.

Respond to industry inputs in its planning and funding so that work is carried out to satisfy real needs.

Build competence in all modes of transfer of technology so that results of technical work are put to use.

Deliver educational and technical services to industry to establish and justify long-term, stable support from industry.

The above points are embodied in the Cooperative Technology Center diagram of Figure 2, page 43. Experience with programs throughout the world and in the U.S. teaches that all elements in this chart are essential to a successful program capable of making significant contributions to a nation's economy.

As is currently proposed, the Cooperative Technology Centers will be directed by a board of directors selected by the sponsoring firms. The Centers will control, regardless of funding source, the intellectual knowledge produced, but must on a reasonable basis (time & cost) provide information to nonsponsoring firms. The government role in the Centers is minimal and revolves around two activities. The first is to provide government funding to establish Centers and support specific projects. The second is to review, on a yearly basis, the Centers' plans, policies and operations for consistency with their articles of incorporation.

*7. Solicit public comment on the proposed program through seminars, hearings, etc*

In the course of our study, more than 250 representatives of industrial firms, universities, professional and trade associations, and a small number from state and local governments have been contacted. The resulting discussions leave little doubt that there are important generic technologies that industry can address only in a cooperative manner. Moreover, there is sufficient interest in the Cooperative Techology Program to justify arrangement-making by Government which will permit industry to spend its combined funds on cooperative technology development. Recognizing the need for aid to industrial innovation and the potential public benefits which could accrue industry, selected universities, government and labor are supportive. And, if industry's concerns can be allayed about antitrust enforcement, the Federal Trade Commission, the Internal Revenue Service and "red tape", this support can be readily turned into action.

*8. Refine the program design and select target industries*

Upon acceptance of the concept and the preliminary design, a follow-on budget proposal will be developed which will address this question in detail.

## I. INTRODUCTION

In answer to Congressional and OMB questions, this report describes the results of a one year study conducted by the Office of Cooperative Technology (OCT) to determine the feasibility of establishing a Cooperative Technology Program (CTP) in the United States designed to stimulate technological innovation. By stimulating technological innovation, this program will help to satisfy important national needs to:

Generate advances in productivity necessary for a growing and noninflationary economy;

Protect environmental quality and human health and safety while enhancing productivity and competitiveness; and

Meet foreign competitive challenges in high technology export products.

An important aspect of this study was the review of past and current cooperative industry-government programs to stimulate technological innovation and its commercialization, both domestic and foreign. From this review a determination was made of those characteristics that were associated with successful programs and the characteristics associated with unsuccessful programs. Summaries of the results of these reviews are in Chapter II of this report and the review reports themselves are published separately as appendices.

Based upon the review, a cooperative technology concept was developed, as described in Chapter III, to be used to measure the feasibility and benefits of a program of this type in nine selected technology and industrial areas.

These areas are: (1) Automated Batch Manufacturing; (2) SemiConductor Electronics; (3) Powder Metallurgy; (4) Welding and Joining; (5) Organic Coatings; (6) Textiles; (7) Corrosion Treatment; (8) Radiation Processing; and (9) Composite Materials.

Working with representatives of industries associated with the nine areas, a detailed examination was made of how the CTP would operate in each area. Extensive interviews were held with high-level industrial officials to examine the usefulness of CTP, and workshops were held in each area to develop an industry consensus. The results of these interviews and workshops are summarized in Section II, with the detailed reports on the individual case studies published separately as appendices to this report.

The general conclusion of this study is that there is outstanding potential for a domestic cooperative technology program, provided the program is carefully managed and remains responsive to the needs of the industries involved. Only with the enthusiastic support of industry and a substantial, long-term commitment by the Federal government can the program succeed.

Being a concept paper, this report does not contain a specific implementation plan or detailed answers to the many questions which have arisen and will continue to arise now that the program is approved. Actual implementation may change some of the ideas or methods foreseen in this report and will certainly require extensive elaboration of the ideas. Still other questions and problems will be impossible to answer accurately in the abstract or solve except on a case by case basis.

## II. COOPERATIVE TECHNOLOGY—ITS POTENTIAL

The objective of this review of cooperative industry-government programs is to identify those program characteristcs that are generally associated with successful programs, and to determine the conditions which explain this association. By identifying these characteristcs and understanding their implications, the design of a domestic Cooperative Technology Program can be developed which will maximize its probability of success.

The examination of the cooperative technology programs and policies was carried out in two steps. First, a brief review identified those countries and programs most relevant to the proposed domestic Cooperative Technology Program. Then, from this review, eight [2] countries were selected and their programs studied with three major objectives:

To identify and evaluate alternatives to cooperative R&D and alternative forms of technological cooperation between industry and government;

To assess the benefits to foreign economies from cooperative R&D relationships; and

To analyze successes, failures and logic of other programs for possible application to the proposed U.S. program.

The details of this review are presented in Appendices 11–19. Section A of this Chapter summarizes the results in terms of a world perspective whereas Sections B

[2] Appendixes 11–19 are reports on the programs of United Kingdom, West Germany, the Netherlands, Japan, Canada, Sweden, Israel, France, and a summary report.

and C describe the U.S. domestic programs from the government point of view (B) and from industry's point of view (C). Finally, Section D presents the conclusions and recommendations derived from the review.

A. *World Perspective*

The review of cooperative technology programs in developed countries around the world yields the following generalizations about these programs and the environments in which they operate.

As an important feature of their industrial and economic policymaking, all countries examined view technological innovation as prerequisite to the maintenance of economic health. This is largely the case since, most developed countries see their economies threatened from two directions: by other developed countries with competitive advantages in science and technology, and by the developing countries with competitive advantages in labor cost and natural resources.

The economies of most of the industrialized countries are more centrally "planned" than the U.S. economy and there tends to be more aceptance of economic planning. Whether they simply evolved or were planned, the policies and programs of other countries have been tailored to suit the unique cultural, economic, and social circumstances of each country.

There are certain cultural characteristics which tend to distinguish the approaches of Japan and the European nations from what might be successful in the U.S. In Europe, there tends to be strong ties to tradition and somewhat restricted social mobility. The Germans have a particular reverence for science and technology, and the adversary relationship between government and industry is significantly minimized by government reliance on an extensive and time-honored advisory committee system. Although French industry may not always like government agencies programs or agents it is always very respectful. Japan, of course, is renouned for a cooperative spirit which is pervasive throughout all levels and aspects of society. It is clear that cultural differences have played a major role in shaping cooperative R&D programs in the various developed countries. The U.S. belief in competition and the adversary nature of relations between Government and industry can help to explain why the U.S. alone of all the industrialized countries has not developed such programs to date.

Selected economic indicators can reveal, in part, the state of industrial technological innovation in the developed countries vis-a-vis the U.S.:

*1. Growth of Government spending on civilian industrial R&D.*—According to the OECD, this growth in 1976 for the U.S. was the lowest of all the developed countries—both in absolute terms and as a proportion of total government R&D spending.

*2. Real growth rate of GNP per capita.*—This growth rate in the U.S. from 1970 to 1975 was lower than that of the other industrialized countries.

*3. Investment of GNP in plant and equipment.*—The U.S. invests a lower percentage of GNP in plant and equipment than its leading competitors.

*4. Productivity growth rate.*— The productivity growth rate in the United States is the lowest among the industrial nations.

*5. Trade surplus.*—In the United States, technology intensive industries in aggregate have a trade surplus, while the non-R&D intensive industries, with the exception of agriculture, have a trade deficit.

Collectively, salient features of the national policies and strategies of other countries can be summarized as follows.

Government policies to stimulate innovation have been the subject of growing attention and actions in the other industrialized countries throughout the 1960s and 1970s.

Early efforts of foreign governments to promote innovation were focused generally on large, advance R&D projects and on "global" approaches (i.e., providing blanket incentives such as tax relief to industry). In some cases, subsidies were provided to "failing" industries. Earlier approaches emphasized the R&D end of the innovation spectrum.

Recent trends in foreign industrial innovation policy show the following changed directions:

Most governments recognize that the very large R&D projects in the past may have reflected lobbying power and deference to science and technology rather than market opportunity. Such projects are being de-emphasized.

The industrialized countries are moving toward support of specific, high-potential industries or technologies, rather than providing global mechanisms or subsidies for declining industries.

Foreign governments now are using a wide array of programs and other policy tools to promote or stimulate industrial innovation. These tools are seen as essential complements to existing R&D efforts.

Foreign countries tend to use their nations' top talent in developing and implementing techno-industrial strategies and policies.

Most of the techno-industrial strategies of the developed world are directed

toward improving the international competitiveness of their industries. The U.S. market is often the specific target.

Each of the other industrialized countries of the world has at least, one (and in some cases several) mechanisms for government support of cooperative R&D by industry, government and universities. In no case, however, are these cooperative research institutions considered to be the only element in government support for industrial growth and development. Instead, such industrial research institutions appear to be embedded in national industrial and R&D infrastructures.

In nearly every case, these industrial research institutions have benefitted greatly from being part of a government-sponsored, national industrial or economic strategy.

Thus, it is clear that the other developed nations of the world, perhaps because they have not had the natural resources and market strength of the United States, have long been concerned about the welfare of their domestic industries. Techno-industrial and economic policymaking in other countries is conducted at the highest levels of government and involves the elite of industry, government and academe. There is general acceptance of a direct government participation in setting industrial policy in other countries and there is more public acceptance of the need for economic planning.

For these reasons and others, the other industrialized countries studied appear to have a 15-to-20 year head start over the United States in the process of formulating and implementing national techno-industrial policy.

*Program diversity*

Most countries have found it useful to have a system of programs each related to a different function in the innovation cycle. Thus, most modern nations have programs which:

Support manpower training and information resources as the indispensable base for science and technology policy;

Support selected areas of basic research and the establishment of fundamental standards and measures;

Provide government subsidies and conditional repayable loans to firms for specific R&D projects;

Support nonproprietary applied research and advanced development in areas related to specific national objectives;

Co-support advanced government research facilities which perform proprietary applied research for firms on a fee-for-service basis;

Support demonstration of risky new technologies when there are compelling national goals involved;

Provide tax credits to stimulate industrial R&D and investments in new technologies;

Stimulate markets for new technology through significant procurements of innovative technologies;

Provide venture capital for the small entrepreneurial firms which are often the source of very new technologies;

Cooperate with other countries in sharing R&D resources, combining markets, joint procurements, etc., where national interests converge.

A coordinated system of programs seems to provide the best results in stimulating industrial innovation. Cooperative R&D programs are one central element in the policies and programs of all other industrialized countries. In fact, many cooperative R&D programs predate the establishment of national industrial or technological strategies and may have provided an impulse toward industry/government cooperation in broader areas. The individual programs vary, but the idea of industry, government and the university working together to advance industrial technology is now fully accepted throughout the developed world—except in the U.S.

*Assessing the benefits of cooperative R&D*

Evaluating the benefits to foreign economies of cooperative R&D efforts is very difficult; no direct benefit/cost analyses were identified during the present study. Some of the assessments that have been performed have been confidential. The cooperative R&D programs are so totally embedded in the total R&D infrastructure that is is difficult to identify and estimate the benefits related to specific programs.

Yet, the programs appear to be well established as a fixed element of the industrial R&D scene. No country appears inclined toward reducing its reliance on cooperative R&D and several have steadily had increased support in this area in the last decade. During the next decade, political and economic developments are expected to place yet more emphasis on industrial innovation and on programs to encourage its growth.

*B. Government perspective*

Unlike the other industrialized countries, there has never been a mandate in the United States for government to provide direct support for industrial technology

development per se. There have been innumerable Federal, State and local programs and projects for development of industrial technology to meet public (government) needs. Government has also assumed responsibility for funding the nation's science base. It has only been in the last two decades, however, that economists and statesmen of science and technology have argued for direct government support of the generic industrial technology that constitutes the technology base for American industry.

Part of the Cooperative Technology study was an examination of Federal, state and local government programs in which government and industry collaborate to promote technological innovation or to develop industrial technology. Although the review obviously could not address every state and Federal agency, from the sample taken it was clear that industry, university and government collaboration in technology development is primarily restricted to programs where the Federal government is the primary consumer, like the defense and space industries.

*1. State and local government programs*

No local government programs which directly promote industrial technology development were identified during the course of our search. However, Nine state-sponsored programs, however, were identified.

Apparently, there has been growing interest by state governments in programs to assist industry in technology development. While their success has been mentioned, those which have withstood the test of time generally have had the following characteristics:

Limited management resources: no more than 30 people, often less than 10.

Restricted as to geographic location: mostly Southeast or Northeast.

Wide diversity of services provided: capital, technical publications, planning and extension services, training assistance, etc.

Political and fiscal shifts inhibit continuity and long-range strategies.

No systematic evaluation of programs; little indication of what works and what does not work and why.

Moreover, we found the States and local governments have neither the funding, specialized personnel, nor the specialized institutions and facilities to collaborate with industry and universities in industrial technology development. Yet, many of these governments have a growing interest in such programs and are considering opportunities to build capabilities to a higher level.

Nonetheless, with only 18% of the states having programs to assist technology development and none identified at the local government level we have concluded that the states and local governments are only minor participants in the industrial technology arena.

*2. Federal programs*

The scope of past and current Federal involvement in cooperative R&D and the range of mix of mechanisms and administrative practices are much larger than generally assumed either in government or industry. Collaborative efforts appear to have become an accepted and expected way of life in public interest industrial sectors such as aerospace, agriculture, transportation, shipping, defense electronics, etc. These relationship have led to steady as well as dramatic technological improvements which reduce costs and increase the benefits to society. Many areas of Government/industry cooperation for technology development also are the area of the greatest U.S. trade advantage today. Additionally, cooperative efforts have proven useful in alleviating institutional restraints to innovation.

There is, however, little Federal government/university/industry collaboration focused on technology for civilian manufacturing, the engine of U.S. industry and commerce. Although industry, government and universities have worked together in the past for mutual benefit, most Federal programs have stopped abruptly when the specific, limited Government need is satisfied (i.e., diffusion and utilization of the technology for commercial purposes have not been part of the goal). In addition, despite the large number of such projects, most have been limited to, for example, the defense or agriculture sectors. Consequently, many other important industrial sectors have not had access to such programs. In short, despite the range, depth and success of certain cooperative efforts, in many areas there is no governmental mechanism for aiding the conversion of technologies into industrial products which increase productivity, help reverse the balance of trade and aid employment growth. The Cooperative Technology Program can help provide this conversion function for some of those technology or industrial areas which are not currently a focus of collective effort.

Administrative practices vary widely among government programs, depending on the particular mission, complexity and status of the technology and/or industry, and the structure of the industry. These practices seem to be more directly correlated to the experience of the agency staff than to agency policy.

Yet, there are no specific administrative procedures which appear to correlate with the success of programs. It may be that specific procedures are not as important as the "working relations" between Federal staffs and their constituencies. Pragmatic, custom-designed and adaptable mechanisms appear to work best.

Our survey concluded that Federal involvement in promoting industrial innovation and productivity is most successful when:

A clear, legislative mandate and measurable goals exist.

A strong "champion" with a technically-competent program staff leads the program.

The program staff is sufficiently experienced in industry to understand the motivation and attitudes of industry executives and of competitive firms. Personnel exchange between industry, university and government of technology.

Relationships, mutual trust, credibility, and the knowledge base needed for best results are developed over a suitable time span.

Hands-on participation by industry in design, implementation and evaluation of the collaborative efforts is an underlying principle in program operation. In cases where technology is developed under Federal and/or State and local control, substantial investment in promoting the utilizing of results pays off (the Agricultural Extension Service is the prime example).

Programs develop or strengthen private institutions for cooperation.

In summary, the message for any new Cooperative Technology program seems to be:

Have a mandate from the Legislative and Executive branches based on generally accepted goals and performance measures.

Involve potential industrial partners in all phases of the program.

Emphasize competence and compatibility with industry in Government staffing.

Plan either to continue cooperative arrangements for long periods (5 to 10 years), or to develop institutions that are able to do so.

Provide for adaptation in program design and administrative procedures.

Tailor the program to the specific industry or industrial technology.

Coordinate and cooperate with the wide range of existing Federal programs.

Recognize that technology base development is only one of many factors affecting innovation.

*C. The industry perspective*

Enthusiastic support and participation by industrial firms is fundamental to the success of the proposed Cooperative Technology Program. Such support on firms perceived self interest will help ensure that requisite enterpreneurial and managerial talent is made available, and that the program is kept on a commercially viable track.

This appraisal of the prospects for industrial support is based on the industry reaction to two questions:

Is the proposed cooperative mechanism seen as desirable and effective?

Are there important generic research projects appropriate to the cooperative approach which are not being adequately addressed by existing mechanisms?

Approximately 250 industrial spokesmen have participated in the study with National Bureau of Standard/OCT staff members. These contacts include industrial research managers and chief executive officers, academic research personnel with strong ties to particular industrial sectors, trade association representatives, leaders of professional technical societies and representatives of interested Federal Government agencies. Many of these interactions occurred during a study managed by the Industrial Research Institute/Research Corporation.[3] Prior to and during that activity, numerous additional industry contacts were made by NBS/OCT staff, by other NBS technical staff, and by means of a series of meetings at NBS and DoC with individuals and groups representing a variety of industry sectors.

Industrial personnel have cooperated wholeheartedly in this study by preparing project descriptions, participating in the workshops, and reviewing draft material; with the following results:

The industrial reaction to the DoC cooperative technology proposal is one of enthusiam for anticipated benefits, tempered by initial reservations concerning the hazards of bureaucratic entanglements. These include major and widely expressed reservations from the industrial participants relevant to direct Federal involvement in R&D, possible anti-trust difficulties, excessively bureaucratic management structures, and the possibility of premature or uncontrolled dissemination of property rights. To the extent that the basis for such reservations will be eliminated, the reaction is highly favorable. Motivations for this positive reaction include an almost universal desire to see the adversary relationship between U.S. industry and the Federal Government changed to one of mutual support. All industrial sectors see a

[3] IRI/RC Final Report Contract No. NB 79–SBCA0039 and see appendixes 1–10.

need for accelerated development of generic technology and are aware of the several economic and social factors which inhibit such development. They also are concerned over increasing market penetration by overseas competitors supported by cooperative national programs of their own.

Many generic development projects with high potential for commercial impact were recommended. In addition, most industries proposed generic projects to improve the technical base for meeting health and safety regulations more efficiently, or to reduce energy costs and usage. There is industry-wide emphasis on the need for enhanced technology transfer which is seen as an invaluable element of the proposed program. The diffusion of new technology is fully as important as the development of the technolgy itself.

Another objective of the cooperative study has been to identity from industry sources R&D program areas favored by industry and addressing critically needed generic technologies. The identification of urgent, industry-wide needs is basic to the proposed Cooperative Technology program. Typical generic technology requirements include, for example:

Development of selected metallurgy data and information on the physical chemistry of metal powder flow to help open up powder metallurgy possibilities for making large complex shapes;

A need in the semiconductor industry for more basic science in short wave-length lithography and exploratory work on new high-speed photo-resists. This work would speed development of new intergrated circuit fabrication techniques;

Various proposals in automated batch manufacturing (broaden technical base of flexible manufacturing systems);

Welding and joining (new applications of automated arc welding); and

Industrial radiation processing (new electron beam source technology).

In addition to proposals for extending commercially oriented technologies, there were two other classes of proposals from industry. Most industry sectors indicated a need for cooperative project to improve the ability to meet new Federal health and safety regulations. This desire was strong, for example, in the welding, organic coatings, textiles and industrial radiation sectors. In all sectors there were proposals for smaller cooperative projects aimed at incremental extensions of current technologies. Whereas many of these projects are inappropriate for government cost-sharing with the private sector, they could well be performed in Cooperative Technology Centers under full industry funding.

Several additional factors which emerged from this study are relevant to implementation of the Cooperative Technology Program:

1. The program involves concepts unfamiliar to many industrial managers and suggests working relationships for which there is little precedent in industrial experience. Because of this limited understanding there is a burden on the government participants to continue working with industry representatives to clarify the proposal and its implications to the greatest extent possible.

2. In discussions and negotiations with industrial firms it is essential to reach and deal with senior management as well as the technical leadership.

3. The program offers an opportunity for industry to expand its efforts in longer range, technology-focused, generic research at reduced cost and risk. This is an area unfamiliar to medium and small er firms and to much of the academic research community. If this opportunity is to be fully exploited, the Cooperative Technology Centers must engage the best technical talent available from industry, complemented by select academic expertise familiar both with the science involved and the industrial realities.

*D. Conclusions and recommendations*

We present here general conclusions and specific recommendations derived from the examination of industrial needs; Federal, State and local cooperative programs in this country; and comparable programs in foreign countries:

All aspects of the study affirm the desirability of the Program. It is generally recognized that the international business climate presents an increasingly serious challenge to the historic American position. Much of the progress of foreign competitors can be attributed to their national cooperative R&D programs which concentrate resources on identified commercial targets—either markets formerly dominated by the United States, or new world market opportunities.

The conclusion that a cooperative approach to industrial R&D in the United States is feasible is based on: the apparent success in other industrial countries of certain cooperative programs with similar features; the willingness of industry to participate in and support the proposed program, provided that certain design and management guidelines are followed; and the past success of a number of relatively ad hoc cooperative programs in the United States.

*1. General recommendations.*—In the appendices to this report, there is a wealth of information concerning possible ways of energizing cooperation among industry,

Government and academia. However, cooperative technology is a new concept in this country, and the design will have to evolve as the program is implemented. It would not be prudent to harden the concept and operating procedures while the dialogue with industry is still under way. Nevertheless, it is possible to highlight the more important lessons learned from the examination of foreign and domestic programs and from the industrial case studies.

It is important for the program to be launched with a public mandate that stresses the Government's commitment to continuity. For example, there might be appropriate explanatory statements from the President, the Secretary of Commerce, the President's Science Advisor, and perhaps by appropriate Congressional Committee Chairmen. The program's initial life could be set at five years to underscore the necessary stability of the CTP. This is an important condition in the thinking of industry leaders.

Most firms are not accustomed to working with each other or with the Government. Therefore, the Government participants should continue working with industry representatives to clarify the proposal and its implications—throughout the implementation of the Program.

No one should speak for industry except industrial leaders themselves. Because of the novel relationships involved, there may be a natural tendency for university and Government people (particularly those with industrial backgrounds) to interpret industry viewpoints—this must be avoided.

The Centers themselves must not be "captive" to either existing industry organizations (e.g., Trade Associations), government or academic institutions. They must be separate non profit corporations responsive to their own management structure.

*2. Design recommendations.*—Design concerns were identified that relate to long-term viability of Centers. The most important remaining issues have to do with the mix of services offered by cooperative technology centers:

Foreign studies show that industrial research institutes tend to emphasize urgent, short-range work at the expense of longer-range industrial needs. The same tendency is increasingly true in U.S. corporate research efforts. The Cooperative Technology Program can help to correct this imbalance. Government can encourage longer-term applied research that few firms—and especially small and medium sized firms—can not do themselves. Such areas that are crucial to the competitive future of the industry should receive preferred support.

Centers that serve industries with limited technical and economic resources require special attention to obtaining quality R&D personnel and effective leadership. Heavy emphasis also is required on transferring technology efficiently to participating firms. The current design plan—that a Center should become self-supporting at the end of a mutually agreed time period—should assure the survival of those Centers of clear and evident usefulness. However, even though it may be relatively easy to establish Centers for trade impacted or low-technology industries, they may be more difficult to bring to a self-sustaining level.

U.S. industry spokesmen are unanimous in urging early and complete development of policies and guidelines—particularly those related to antitrust, confidentiality of data and patent rights. The foreign experience, however, tells us that the design must be open enough, within those policies and guidelines, to permit difference among centers and industries according to need.

Both technology-oriented and industry-oriented research institutes abroad have experienced difficulty in developing a user community. It is clear that each CT center will have to address the problem of developing its industrial clientele. Training and testing services, and demonstration programs are recognized mechanisms abroad for attracting and holding long term user interest.

The innovation literature indicates that most innovations fail not because of technical problems, but rather for diverse reasons such as inadequate capital, lack of communication, poor management, or marketing deficiencies. It is important, therefore, that the centers offer certain complementary services that will facilitate and encourage the successful application of their technical results.

*3. Implementation recommendations.*—Program acceptance will rely on early evidence of success to win the industrial support needed for its longer-term viability.

The United States possesses a rich and varied industrial technology infrastructure. The success of the Program will depend on using existing institutions and programs so as to enhance their value rather than to duplicate their services.

In particular, the selection process for center sites should take into account not only universities but also the private not-for-profit research laboratories which are a significant factor in U.S. industrial research. Many of these institutions have excellent staff and modern facilities together with an established base of industrial support. If these laboratories can adapt to the requirements of the Cooperative Technology Program, this would facilitate early establishment of Centers in the related technical areas.

State and local governments appear not be active participants in the industrial R&D situation. In the interests of local and regional development, however, they are likely to become more involved in this area. It will be necessary to find a way for these governments to participate at some level and to make available State and local resources (e.g., State university and venture capital programs) that would be helpful to the Cooperative Technology Program.

## III. COOPERATIVE TECHNOLOGY—AN EMERGING DESIGN

The design of the CT Program has as its major goal the effective use of Federal funds to provide significant public benefits through stimulation of technological innovation and its commercialization. To satisfy this goal, the program design includes characteristics identified with successful industry-government cooperative efforts both here and abroad, which are described in Chapter II of this report.

The program design is expected to evolve in response to the industrial innovation needs of domestic industry and will be modified as needed to take into account operating experience. Currently thinking on the program design is discussed in sections A through C of this chapter which address: A—Design framework and principal organizational elements; B—Program functions; C—Important design considerations.

### *A. The design framework and principal organizational elements*

Figure 1 shows the organization of the CT Program in terms of two organizational components: (1) The Office of Cooperative Technology (OCT). (2) The Cooperative Technology Centers (CTC).

Each element plays a specific functional role that is necessary for program planning, execution, and supervision. The OCT is responsible for: the formulating of policy and plans for the program, assisting the management making; performing the detailed economic analysis, developing technology and market assessments, as will long term strategies analysis of the world wide state of relevant technologies, and the evaluation of program performance. The CTC's are nonprofit coroporations which under the direction of their private sector management structure will execute the generic research agenda's and related technology diffusion functions. It is their work that ultimately will determine the success of the CT program.

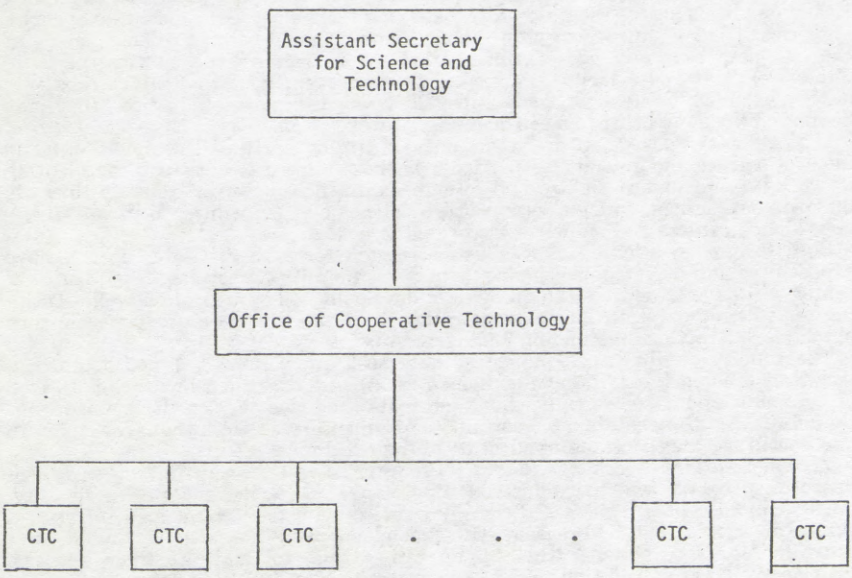



Figure 1

*1. The Office of Cooperative Technology (OCT)*

The Office of Cooperative Technology (OCT) and its Director will report to the Assistant Secretary of Commerce for Science and Technology. OCT will be responsible for long-range strategic program planning, formulation of policy, and the day-to-day operations. The conduct of these responsibilities would involve the following principal activities:

a. Evaluate various industry sectors and technological areas for their CT Program potential.

b. Select industry sectors and technology areas as candidates for the CT Program.

c. Maintain close contacts with trade and industry groups in those areas that are currently participating in the CT Program or are possible CT Program candidates.

d. Collect industry data necessary for industry sector analysis.

e. Collect data necessary for technological forecasting and assessments.

f. Perform CTC planning and implementation.

g. Monitor CTC operation and evaluate results.

h. Perform economic and policy analysis to determine impact of CT Program. This will involve the development of new methodologies in economic analysis.

i. Interface with appropriate government agencies involved with technology development, assessment, and/or data collection concerning technology developments, both foreign and domestic.

j. Collect and analyze information on other domestic and foreign cooperative technology efforts.

In carrying out its functions, CTP will draw upon appropriate outside advice as the need arises.

*2. The Cooperative Technology Center (CTC)*

The CTC, the key element in the CT Program, will be a private, non-profit organization which will perform generic technology development and promote technology transfer in a specific technology or industry area. Each CTC will perform the following functions (Figure 2 presents the functional structure of the CTC):

a. Applied research and advanced development.

b. Consulting and technical services in the area of the specific technology.

c. Database maintenance and information services.

d. Labor and management education.

e. Technology transfer and utilization.

Each CTC will have a Governing Board made up of representatives from the participating firms which will be responsible for the management of the CTC. The Federal government normally will not be represented on the Board and will not be involved in direct CTC management.

The CTC will perform a major portion of the generic R&D program R&D in-house. This direct experience with the technology will help insure that communication gaps do not develop between researcher and potential industrial user. It will have formal ties with user firms so that the CTC will be fully responsive to the needs of industry.

# CENTER STRUCTURE

## What will be the structure of a Cooperative Technology Center?

A Cooperative Technology Center will be structured as shown below:

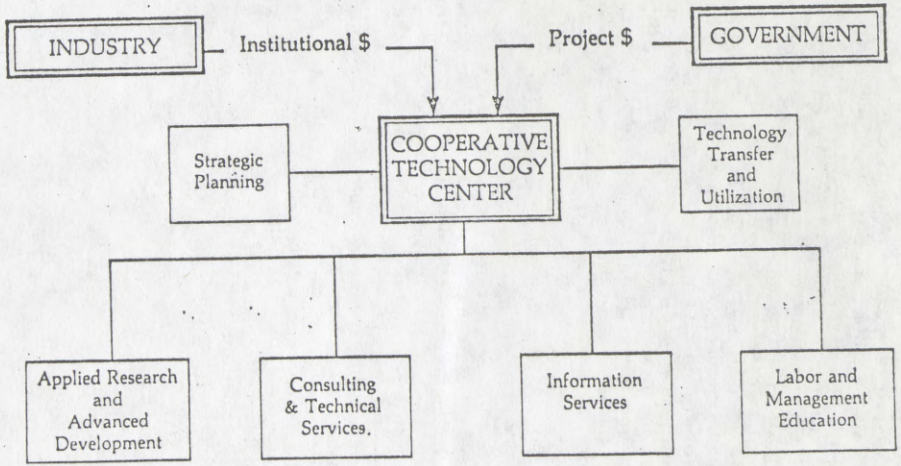



Figure 2

*B. Cooperative technology program functions*

As currently envisioned, the CT Program will incorporate the following four major functions:

*1. Selection of technological areas for the CT program*

The OCT will select industrial technology areas based upon comparative analysis of their importance to the domestic economy and their potential suitability for the CT Program. The following criteria are indicators of this suitability.

a. The industrial users of the technology must currently or potentially be an important element of the domestic economy; the industry's potential should depend significantly on technology development.

b. The efforts needed for the advancement of the technology will probably not be undertaken without some Federal support due to inadequate industrial resources, limited appropriability of the results of the R&D, or industry structure.

c. Industry must be willing to support one or more Centers in the technology area through the commitment of funding, manpower, or other resources.

As experience is gained the OCT will establish program priorities for the various technology areas, which will be used to determine the level and timing of Federal support.

As part of OCT's analysis, a determination will be made of the current status of those firms and industries that are major users and producers of the technology, as well as an estimate of future trends (assuming no government-aided cooperative efforts). This will involve both a sectoral micro-economic analysis and a technology assessment that take into account domestic and foreign developments. Then, a hypothetical CT initiative specific to the technology will be developed so that its impact on the technology and on the using industries can be estimated. Finally, a benefit/cost study will attempt to determine whether the benefit/cost ratios are adequate. Priorities for funding and scheduling will be influenced accordingly.

*2. CTC planning and implementation*

The first CTC planning step will be to develop a detailed project list based on the initial analysis of the technical area and extensive industry coordination. Additional projects may be identified through joint industry/OCT workshops which will include by representatives of major users and producers of the specific technology. In these workshops, an attempt will be made to reach a consensus as to relative priorities of projects the industry wishes to pursue. Based on the preliminary project list, an initial funding schedule for institutional support of the CTC will be derived to serve as a basis for planning.

Next, a survey of existing organizations having competence in the technology area will determine whether one or more of them can be adapted as CTC's. This survey will examine these organizations in the following terms: (a) type of work currently being done; (b) Organizational structure; (c) Source of financial support; (d) Facilities and equipment; (e) Personnel qualifications; (f) Reputation and industry acceptance; (g) Expertise and past experience; (h) Willingness to participate.

Once a determination has been made that an existing organization or institution can be adapted as a CTC, a five-year CTC development plan will be generated. This plan will assume that institutional funding by the Federal Government on the average will be phased out by the end of the fifth year at which time the CTC should be largely self supporting. The Government, however, may continue to support specific projects beyond this initial five year period.

*3. Selection of CT projects for Government support*

The determination of whether a proposed R&D project qualifies to receive Federal CT funding will be made by OCT, considering the following initial criteria:

a. The project's expected impact on the development or advancement of the technology, and the probability of success.

b. Necessity of Federal support for initiation of project.

c. Demonstrable and significant public benefit of the project, if successful.

d. A satisfactory level of support by industry.

e. The project's priority ranking and budget permit its funding within available CTC resources.

A proposal for a CT project can originate from a CTC, from industry, universities, professional societies, or even from the OCT. The proposal must contain sufficient detail to permit the OCT to determine whether the evaluation criteria are satisfied. This will require both an economic and technological analysis to validate anticipated project costs and impacts. In addition, the project must be related to the total available CTC resources.

*4. Evaluation of program performance*

The basic building block for decision-making and for measuring program performance is the individual research project cost/benefit analysis. In this manner the disparity in size, risk, cost, etc., of various research projects can be taken into account. Each analysis sets the expectation for that project, provides the justification for funding it and establishes goals against which its success can be matched. In addition, these building blocks, when combined, represent an agenda or research program on which a given technology or industrial area may initially be selected and a center established to carry out the work, and against which the performance of that center can be judged.[4]

*C. Design considerations*

In the development of the program design, the following considerations were taken into account: (1) Anti-trust considerations. (2) The CTC funding process. (3) CTC membership. (4) Handling of technical information.

*1. Antitrust consideration*

Prior to the establishment of a CTC, and before substantial public or private project funds are committed, the Department of Commerce or the private sector sponsors, will submit a request to the Department of Justice for a letter of intent not to prosecute joint research activities. Based on Commerce correspondence with the Department of Justice and past examples of letters of intent, it is clear that most requests will be considered on a case-by-case basis, and will probably include several issues which we have broadly interpreted as follows:

*Membership.*—In general open membership is desirable. In most industries, Justice feels that broad membership of domestic firms will increase the competitiveness of the industry. However, in some cases the effect might be anticompetitive. Justice would, therefore, decide on a case-by-case basis. It is however, that blanket restriction against foreign membership in most cases would be discouraged.

*Dissemination of results.*—Nondiscriminatory access to the results of joint research is encouraged, including the provision for nonparticipant access to such information, at a reasonable cost.

*Basic versus applied industry knowledge.*—The more closely the results of joint R&D approach specific manufacturing processes or practices, the more difficulties Justice foresees. The more basic such knowledge is to the industry the less likely there is to be reservations.

The primary interest of antitrust enforcement is to maintain and increase present levels of competition. Clearly, the goal of the CTP and industrial innovation in general is the increased competitiveness of U.S. industry, both domestically and in foreign markets. Further, most of the CTP activities will be focused on technologies rather than on industries. To date the Department of Justice has granted the overwhelming majority of requests for letters of intent not to prosecute in the case of joint research, and according to Justice it has never subsequently prosecuted. For these reasons, we expect to alleviate any Federal antitrust concerns on the part of industrial participants.

*2. CTC funding process*

*a. Legal authority.*—The second paragraph of 15 U.S.C. 1525 authorizes the Secretary to engage with "non-profit organizations or agencies * * * in joint projects * * * on matters of mutal interest, the cost of which shall be apportioned equitably, as determined by the Secretary * * *." The interest of the Secretary in assisting domestic industry has been recognized by Congress in the Department's organic legislation and relevant statutes. In initiating this program the Secretary and the Center will express a common interest in: (1) the strengthening of existing centers of competence or the establishment of new ones; and (2) the funding of specific projects for such activities.

*b. Funding patterns.*—Two types of Government funding arrangements are proposed. First, the provision of institutional funding which would be used to initially seed the establishment of Cooperative Technology Centers and would be expected to decline over several years as Centers become self supporting. Second, the provision of project-specific funding which would be used for specific R&D activities. The provisions of first and second state funding will be governed by the following budget policy.

No support is expected to be given for the construction or general reconstruction of buildings.

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[4] Nowhere in our world wide study have we found useful criteria for selecting cooperative efforts. Consequently, our efforts in developing performance criteria must, of necessity, evolve as we gain operating experience.

No funding is anticipated for collective benefits to industry which are not tied to specific technologies.

Continuing Federal funding of a Center will depend on attainment of reasonable targets for industrial support.

Centers will not utilize Federal funding to initiate direct competition with private organizations (e.g., consulting firms and testing laboratories).

*3. OCT membership*

*a. Center.*—It is proposed that Centers be required to admit to membership any domestic non-governmental entity in business or industry. Foreign membership policy will be determined later. Membership fees should be designed to encourage membership by firms of all sizes and financial strength. Fee schedules should consider: 1) size of entity, 2) volume of activity relevant to the technology, 3) directives of interest (potential use of the results of the Center's work).

*b. Governing board membership.*—The Governing Board will be elected each year in a manner in which will ensure fair representation of the interests of all members. No Federal employees who are involved in the management or funding of this program will be eligible to serve on a Governing Board in any capacity.

*4. Handling of technical information*

As it is currently proposed, the CTC would own any technologies it developed and would have the power to license patents. Royalties could be collected and used for further research and development, but not to reduce membership fees. However, if the technoloby is critically and competitively important, a license would have to be granted to nonmembers although they can be charged a higher royalty rate. All services can be exclusive to members of the CTC except those that are deemed critically important in a competitive way. Founding members would be in a different position from new members who can be charged an additional fee in consideration of prior development costs.

## IV. SUMMARY

Although formal cooperative technology mechanisms to enhance industrial innovation are relatively nonexistent in the United States; it is a fixture in the array of mechanisms used by our major trading partners. This study surveys the pertinent aspects of foreign cooperative programs and the concept for a program in the United States. Such a program has been approved by the President.

The Department of Commerce, Office of Cooperative Technology will undertake the task of dealing with issues of implementation during FY 1980, realizing that some issues must be solved largely on a case-by-case basis and that experience will modify current plans. The formal CT program approved by the President begins in FY 1981, at which time the first experimental centers will be established. Monitoring of both domestic and foreign cooperative programs and technology developments will continue throughout this timeframe. After the initial effort, it is anticipated that sufficient interest will permit the program to expand well beyond the first few centers.

While the concept is new to the United States, it appears to be both adaptable to the American techno-industrial system and potentially very valuable to the national economy.

*Question 2:* Status and findings of the Department of Commerce's study on the Cooperative Technology Program, including the proposed generic technology centers. Specifically, information on (a) how the centers would operate, (b) how priorities would be established and what criteria would be used, and (c) the role education would play, and (d) the role advisory services would play.

Response: The status and findings of our study are reflected in the IRI study of nine industrial areas and our own analyses of domestic and foreign activities (enclosed). We are still modifying the design chapter of the study to assure flexibility and an optimal fit into the U.S. industrial infrastructure. For example, it has recently become clear that the policy and technology advisory boards originally envisioned may represent a burdensome superstructure to the effective and timely execution of generic centers. Consequently, these arrangements are undergoing substantial rethinking. Nonetheless, the remaining chapters adequately portray the environment as we now see it.

## I. STATUS OF DOC COOPERATIVE TECHNOLOGY STUDY

Report attached.

II. GENERIC TECHNOLOGY CENTER

*Center operations, priorities, and criteria (sections (a) and (b))*

The operation concept is best described by starting with the selection process for the technology areas and then moving to the proposed method of operation. It must be remembered, however, that our intent with regard to both selection and operation is to be sufficiently flexible to meet the unique requirements of the technological needs of industry. Consequently, as we gain actual operating experience, the procedures described will be modified to provide maximum benefits as well as to minimize operational problems.

The selection of generic technology areas by the Office of Cooperative Technology (OCT) will be based on the estimated benefit-cost ratio associated with the research agendas of the proposed centers and will be prioritized according to their potential contribution to: (a) an increased rate of industrial innovation, (b) an improved productivity growth rate, (c) an improved balance of trade, (d) reduced inflation, (e) increased employment opportunities, and (f) other public benefits.

The creation of a center will take place through an ad-hoc planning group consisting of selected interested firms that are representative users, producers, or suppliers of the specified technology. Working with the OCT, the planning group will assess the need for and potential contribution of a center. Assuming the opportunity is attractive, the group will develop a corporate charter and by-laws for the center and a tentative five year research project plan.

The research plan will be cooperatively developed with industry and OCT through extensive public and private sector dialogue and critical workshop analysis. It its final form, the plan will include those projects which meet, as broadly as possible, the private sector's investment criteria and OCT's criteria for being generic and relevant to national needs. (In this regard, it must be recognized there is no domestic precedence for the development of these criteria. Consequently, even at this writing, the criteria are still under development.)

After the development and approval of the research agenda, a detailed set of requirements will be developed for facilities, equipment, personnel, and funding. A funding schedule will be negotiated with industry that specifies the funding requirements for both industry and government for the first five years of center life. Concurrently, a survey will be made of existing organizations that could serve as a basis for, or could be converted into the center.

Prior to its establishment, the center plans would be reviewed by the Justice Department and the FTC to make sure that the antitrust and FTC guidelines are accommodated. The OCT will review the operations of each center on an annual basis to make sure that the center is operating within its charter. In addition, the OCT will review a center's project plan whenever the center wants to make modifications in its project list.

These centers will operate as non-profit corporations which at a minimum will provide in specific generic technology areas: (a) Applied research and advanced technology development, (b) consulting and technical services, (c) information services to members concerning the technology, and (d) management and labor training in the use of the technology.

These centers will receive partial institutional funding, on a declining basis, from OCT for about the first five years of the life. The balance of the center's funding will come from the industrial members of the center. Each center must become self-supporitng within the first five years. As OCT support declines, industrial support must increase and ultimately become sustaining. Consequently, the burden of continued life rests with the industrial sponsors. Additionally, throughout the center's lifetime OTC will entertain the direct funding and/or the brokerage of funding from other agencies for appropriate projects that would contribute to the center's generic technology objectives but which would not be performed by the center alone.

The centers will be managed as a business by a Board of Directors elected by the sponsoring firms. We do not anticipate Government representation on the Board.

Initially, each year, the OTC will evaluate the activities of the center and its project results to determine how well the Cooperative Technology Program is working and the need to modify the operating guidelines.

*The role education would play (section c)*

Clearly, education plays a key role in the development and diffusion of any technology and particularly that which is generic. However, the development of formal educational programs, such as undergraduate and graduate curricula, is not viewed as an appropriate objective for the centers. More properly, that is the role of our educators, other sponsoring agencies and direct industry initiative. Yet there is a vital, even though less formal, education/training role for the centers. For exam-

ple, we expect one of the near term income producing activities of the centers will be the conduct of training classes and seminars for both members and non-members. Primarily these will relate to the technological competence of the center itself. (But they may also include subjects of a broader nature such as production planning and control, group technology, purchasing, budgetry, behavioral factors, etc.) Additionally, the center also will develop briefings, films and other communications concerning the status and future developments of relevant technology, applications, and markets to increase the awareness of industry, government and the public.

We are keenly aware that the success of our efforts depends on the ability to effectively promote the diffusion and utilization of the centers' technology and that the education/training role is extremely important. Moreover, we are prepared to assign even more emphasis to this area should the need become evident.

*Advisory services (section d)*

As identified earlier, consulting and technical services (Advisory Services) are a major element of the centers' activity. Like education/training these services are viewed as early income producers and key ingredients to enhancing the relevance of the centers not only to their sponsors, but also the equally important universe of medium and small size firms which may not be sponsors. These smaller firms, however, have unique potential for utilizing the centers' technology developments and general expertise. Moreover, we expect, these services will embrace a broad spectrum of individually tailored activities as well as testing capabilities, products, materials, designs, software, etc.

*Question 3.* Background materials that serves to explain and support four proposals made by the President to establish: (a) a Center for the Utilization of Federal Technology; (b) Foreign Technology Utilization Programs; (c) Corporations for Innovation Development; and (d) a Presidential Award for Technology Innovation.

I. CENTER FOR THE UTILIZATION OF FEDERAL TECHNOLOGY

*Statement of purpose and need.*—The goals of this program are to improve the economic health and growth rate of U.S. firms as well as to increase the world competitive position of American industry. An important contribution toward the accomplishment of these goals can be obtained by assisting American firms, both large and small, to utilize technologies that are available to the federal government. These sources include technologies that have been developed within the federal laboratory system, and those developed by federally funded R&D efforts in the private sector.

The initial seeds for the CUFT program already exists in the Department of Commerce. The National Technical Information Service (NTIS) operates a patent licensing program which seeks to increase the private sector utilization of Government inventions by bringing the best of these inventions to the attention of prospective licensees in industry. The major functions are:

To provide centralized public invention announcement services for all agencies. Approximately 2,400 patent applications and patents are announced annually.

To provide centralized licensing evaluation, promotion, foreign filing, and licensing for agencies that do not operate their own invention promotion and licensing programs (Departments of Agriculture, HEW, Interior, Air Force, Army, Veterans Administration and National Science Foundation).

To select and promote the most commercially promising Government inventions, and to license these to encourage wider use of Government technology (8 inventions were licensed in FY '79).

To obtain foreign patents on selected inventions to protect foreign markets and prevent unrestricted and uncompensated use of Government technology by foreign industry.

While valuable to the extent of its scope, this NTIS program must intensify its efforts to meet the future challenges. Between now and year 2000 U.S. producers will face increasingly more sophisticated technological competition from the world's industrial countries, both for the U.S. and foreign markets. These circumstances require a centralized coordinating office to achieve an alignment between the technial accomplishments and capabilities of federally sponsored research on the one hand, and the needs and opportunities of private American technical and industrial firms on the other hand.

The American technological lead, that has been so important to U.S. growth and prosperity in the decades following World War II, has gradually been diminishing. This could place increasing pressure on our balance of payments, and severe constraints on U.S. employment and growth if not counteracted. To date, the Federal Government has not taken unified collective actions to utilize the vast store of

technological capabilities being developed within its own establishment nor to inform itself fully with regard to foreign technology. The program outlined here addresses itself to these needs.

*The opportunity*

In 1980 the Federal government will undertake approximately $10 billion in R&D at federal laboratories and federally funded R&D centers. The capabilities, interests, and activities of these research institutions, while sensitive and responsive to the needs of the sponsoring agencies and involved industries, are generally poorly linked to other industrial sectors. In addition, no focal point exists for these activities within the Federal Government capable of aggregating the scientific and technical information being generated, assessing its relevance to "other" industrial sectors, and disseminating it appropriately. A similar deficiency exists with regard to communicating a more general industrial perspective to the federal research institutions so as to sensitize them to the interests of industry and to the industrial relevance of ongoing R&D within the laboratories and research centers.

*Program Description*

*Goal*

The goal of this program is to utilize the vast store of technological information and development being generated in federal laboratories and federally funded R&D centers. By providing more effective access and promoting innovative application of Federal technology, this program will enhance the growth of U.S. industry, retain current market competitiveness, increase job opportunities, improve balance of payments problems, and strengthen the world competitive position of U.S. industry.

*Major objectives*

To increase the utilization of federally funded R&D developments within the industrial sector.

To produce and maintain a current centralized director of information including technologies available from Federal sources, Federal programs in progress, industrial technological needs, and foreign programs and trends.

To increase the awareness of Federal laboratories and federally funded R&D sectors to the needs and opportunities existing in all industrial sectors.

To plan, organize and conduct conferences centered on a particular technical area and designed to bring together potential technology users from the industrial sector and technology producers for interchange of both information and viewpoints.

To strengthen the U.S. position in world markets by improving the technological knowledge of U.S. firms.

*Program activities*

The CUFT program activities will:

(A) 1. Work with industry (in part through cooperative technologies, in part through the sectoral analysis section of Commerce, and in part through its own outreach activities) to determine industry needs and opportunities for technological advances in productivity, product design, etc. It will communicate this information about industry needs and opportunities to appropriate mission agencies and associated federal laboratories and R&D centers. Finally, it will actively promote technology transfer when an appropriate opportunity has been identified, on an exclusive basis if deemed desirable.

2. Conduct conferences for the interchange of information, viewpoints, requirements and approaches, consistent with the conduct of innovative industrial developments, involving both potential industrial users and Federal personnel. Each conference will be devoted to a single technical area.

3. CUFT will work with technology utilization programs at those mission agencies that have them and directly with other agencies, to:

a. track both completed technologies as well as incompleted technologies;

b. assist mission agencies in determining the relevance of mission oriented technologies to fields of use other than those directly pertinent to the mission agency;

c. assist in the transfer of completed technologies, and in the spin-off of earlier rejected technologies, to applications having different requirements for the anticipated government use.

(B) CUFT will act as the marketing and licensing agent for federal patents in sectors of industry and fields of use with which the mission agencies have little familiarity. It will seek to identify possible licensees and to overcome obstacles to the issuances of licenses.

(C) Utilizing all information obtained from the various activities listed, CUFT will produce, assemble and maintain a centralized information system. The data base will include completed and incomplete technologies from both Federal and foreign sources; industrial technological needs, opportunities and interests; and foreign licensing, information exchange agreements, and joint venture opportunities. This data base is expected to be particularly valuable to small business which has little capability to access this information by its own efforts.

*Outputs*

The activities planned for CUFT center around a searching analysis of industries and firms that are receptive to, and needful of, the transfer of Federal technology for their benefit. The in-government corollary is in coordination of R&D sponsoring federal agencies in order to bring all of the available resources to bear on the requirements and opportunities of industry. This will be accomplished by the operation of a coordinating board represented by all the R&D sponsoring mission agencies. Specific transfer opportunities to individual companies and specific transfer needs can be documented and circulated to appropriate users. A central clearinghouse for inquiries from U.S. industrial firms will be established, and a procedure to process such inquiries will be designed. Federal patents made available to CUFT will be actively marketed and licensing arrangements concluded by the CUFT personnel.

*Program impact*

The benefits to be derived from the program in the area of Federal technology involve the generation of a greater and more rapid return on the investment of Federal dollars in R&D. Technologies transferred to individual firms and across industries will enhance their capabilities and growth. Mission agencies will be better able to carry out their primary responsibilities by virtue of the cross sectoral flow of scientific and technical information. A central organization will be better able to accomplish these goals than will numerous, uncoordinated activities on the part of the individual agencies.

The CUFT program will provide assistance particularly to medium and small technology-based firms whose health and growth are so vitally dependent upon technological knowledge and development, but whose ability to access federal technology is limited. This capability will be enhanced by the establishment of CUFT, by its ability to promote face-to-face interchanges with Federal programs and by its capability to issue licenses to Federal pantents, on an exclusive basis when deemed necessary for successrul commercialization.

## II. FOREIGN TECHNOLOGY UTILIZATION PROGRAMS

For many years following World War II, the flow of technology among the industrialized nations was primarily a one way proposition from the United States to the rest of the world. Now, even as we seek to reestablish and maintain our world technological leadership, we must recognize that we possess no monopoly on technological intellect nor on vital R&D activities. Germany and Japan have made exceptionally good use of published American technological advances. We would be remiss in this day and age not to reciprocate.

This program will provide for locating, acquiring, abstracting, indexing and announcing to U.S. industry selected foreign technical literature. The program includes translation of the most important technical literature items and making this information widely and easily available to industry. Contractor support will be used for acquisition, selection, abstracting, indexing, announcing, and translation activities of this program.

No such unified Federal program currently exists and industrial capability in this area is spotty while small businesses suffer a near loss of foreign technical development information.

## III. CORPORATIONS FOR INNOVATION DEVELOPMENT

While changes in the ERISA regulations and the changes in the capital gains law have freed up innovation capital, it has been primarily focused on second stage financing of companies. It is still enormously difficult to get funding for start-ups, particularly those start-ups where there is significant technical uncertainty.

In the President's decision on innovation it was decided to fund two corporations for innovation development that will work as follows:

1. The corporations are to be not-for-profit organizations financed by a single state or a group of states using whatever financing mechanisms are available to them.

2. That financing, which provides the equity capital for the not-for-profit organizations will be supplemented by loans either directly from or guaranteed by the Federal Government in an amount not to exceed the equity capital or four million dollars, whichever is less.

3. The means to be used by the Corporations for Innovation Development to finance new companies are not to be limited. They may provide loan capital, they may take an equity position in the new company, they may use convertible debentures, or any additional mechanisms or combinations thereof as long as they are legal.

4. The Corporation for Innovation Development will be expected to provide managerial assistance to the new companies in the form of accounting help, guidance in the rules for forming corporations in their states or regions, assistance in working with the Federal and state government on publicly funded projects, etc.

5. Where Federal programs are available (e.g., through the Economic Development Administration) to foster private sector development in a state or region, the Corporation for Innovation Development will be organized in a fashion that will allow it to serve as a recipient of such funds and a conduit of such funds to small businesses.

Corporations will be established after we have requested proposals from states or regions that indicate the range of services they will provide and the extent of their financing. These proposals will be judged on their potential impact on their local area, and on technological innovation in general, as well as upon their management plan that provides for them to become self sufficient after a period of years.

### IV. PRESIDENTIAL AWARD FOR TECHNOLOGY INNOVATION

The President wishes to personally encourage technological innovation and believes it to be altogether proper for the Office of the President to associate its prestige with outstanding successes in this area. Raising the visibility of accomplishments of this kind will motivate and encourage a number of potential recipients and will put the government on record, in a most positive manner, as recognizing the national importance of technological innovation and innovators.

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