90th Congress, 1st Session — SENATE — Document No. 15

POLICY PLANNING FOR TECHNOLOGY TRANSFER

A REPORT

OF THE

SUBCOMMITTEE ON SCIENCE AND TECHNOLOGY

TO THE

SELECT COMMITTEE ON SMALL BUSINESS
UNITED STATES SENATE

PREPARED BY

THE SCIENCE POLICY RESEARCH DIVISION
LEGISLATIVE REFERENCE SERVICE
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SENATE RESOLUTION 93

Submitted by Mr. Smathers of Florida

IN THE SENATE OF THE UNITED STATES,
Agreed to April 6, 1967.

Resolved, That there be printed, with illustrations, as a Senate document, a report of the Subcommittee on Science and Technology of the Select Committee on Small Business, entitled "Policy Planning for Technology Transfer", prepared by the Science Policy Research Division, Legislative Reference Service, Library of Congress.

SEC. 2. There shall be printed four thousand additional copies of such document for the use of the Select Committee on Small Business.

Attest:

FRANCIS R. VALEO,
Secretary.

LETTER OF TRANSMITTAL

MAY 1, 1967.

Hon. GEORGE A. SMATHERS,
U.S. Senate, Washington, D.C.

DEAR SENATOR SMATHERS: I am enclosing a special report prepared for the committee's Subcommittee on Science and Technology. The report, which is entitled "Policy Planning for Technology Transfer" and was prepared by the Science Policy Research Division, Legislative Reference Service, Library of Congress, has the unanimous approval of the members of the subcommittee.

Truly,

JENNINGS RANDOLPH,
Chairman, Subcommittee on Science and Technology.

LETTER OF TRANSMITTAL

LIBRARY OF CONGRESS,
LEGISLATIVE REFERENCE SERVICE,
May 1, 1967.

Hon. JENNINGS RANDOLPH,
Chairman, Subcommittee on Science and Technology,
Select Committee on Small Business,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: In response to the request you made in July 1966, I am pleased to transmit the report "Policy Planning for Technology Transfer," prepared by the Science Policy Research Division of the Legislative Reference Service. The report contains an analysis of issues in obtaining the maximum benefits from Federal investments in scientific research and development. A survey has been made of previous congressional concern and of the present Federal agency programs for technology transfer. Questions are outlined which may merit further consideration by your subcommittee and the Congress.

Mr. Richard A. Carpenter, senior specialist in science and technology, is the principal author and director of the study; he was assisted by Mr. Dennis W. Brezina, who wrote section VI, Mrs. Eleanor Kramer, and Mrs. Maria Grimes, all of the Science Policy Research Division. Valuable guidance and discussion was provided by Mr. William McInarnay and Mr. Blake O'Connor of the staff of your committee. I would also like to acknowledge the cooperation of executive branch agencies in providing detailed information on which much of the report is based. A number of persons reviewed the material in draft form and their contribution is appreciated.

Sincerly yours,

LESTER S. JAYSON,
Director, Legislative Reference Service,
Library of Congress.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

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POLICY PLANNING FOR TECHNOLOGY TRANSFER

I. SUMMARY AND CONCLUSIONS

SUMMARY

Technology transfer is the process of matching solutions in the form of existing science and engineering knowledge to problems in commerce or public programs. The application of technology occurs without any specialized effort but the rate may be less than desired and much available information is lost and wasted.

Existing facts and know-how are a supplement to directed research and development in supplying technology to innovators. The Federal Government "controls" (sponsors, directs, is responsible for) a large reservoir of technology ranging from research results, to practical techniques and devices, to patents. Much of this is potentially useful to much of private industry if the transfer process itself does not add too much cost to the information.

Two critical phases are apparent in the transfer process. In the first, special efforts are required to identify and report new technology which is in the gray area between science and patents. Scientific data are reported systematically through the literature and patentable inventions are accessible. The bits and pieces of knowledge which lie in between are also useful in additional applications but often never are recognized, recorded, or packaged for organized dissemination. The responsibility for identifying this technology must be placed near the point of origin, probably with the R. & D. worker himself.

The second critical phase is in the identification of needs for new technology. Economic growth does relate to technological change but business problems (especially in firms with limited technical staffs) often may not be analyzed so that technological solutions are recognized. Industry will make efforts to obtain whatever it needs to solve its problems—whether that be capital, sales, or technology—once the analysis is made. A technology transfer program therefore must include special efforts to improve the technical literacy in business and to provide counseling for need recognition where the firm may be small or unsophisticated. After 20 years of steadily increasing major expenditures, the general public awareness of the impact of science and technology is still inadequate.

The part which the Federal Government can play in fostering transfer of federally controlled technology ranges from mere publication availability to active development assistance in new civilian applications. Within the Government there is the question of whether all agencies should combine their technical results for centralized processing. Technology collection may well become an adjunct to scientific information handling and be coordinated by the same Federal mechanism. *Dissemination should be centralized at least* *to the extent that the industrial user need contact only one agency for access to all technology in a given field.*

In the private sector, universities and independent research institutes can be effective transfer agents but do not have financial support to initiate extensive programs. If a Federal responsibility for transfer is accepted, the stimulative Federal funding of regional efforts through research institutes and industry oriented universities would be valuable. Industrial support may sustain much of the dissemination cost but transfer institutions should have other funds to do missionary work with firms who are not able to pay their own way into the technology transfer process.

Federally controlled technology should be examined more thoroughly for secondary application to other agency missions and to new public purposes as they arise. In this case the transfer is within the Government. The process is much the same however, and the person-to-person contact is most important.

Existing Federal policies vary among agencies. At the outset, some Government-sponsored R. & D. is performed expressly for transfer to industry and the transfer mechanism is built in (for example, the Department of Agriculture, the National Institutes of Health, or the Office of Coal Research in the Department of the Interior). This technology may also have secondary utility but much of the work of making it available has already been accomplished. No direct analogy should be drawn between such purposeful Federal support and the problem of transferring technology which has been acquired for missions within the Government (for example, Atomic Energy Commission, Department of Defense and National Aeronautics and Space Administration). Overt transfer programs are underway by the AEC and NASA. The DOD sees no necessity for special dissemination and application efforts because its patent policy is supposed to provide the incentive for private transfer programs. However, the security and administrative restrictions on DOD reports keep about one-third of *all* federally controlled technology out of the conventional information retrieval system.

The State Technical Services Act has established a responsibility for aid to industry in applying technology. The early results of this jointly funded Federal-State program indicate that business management in many regions is unaware of the opportunities in applied research and technology utilization. Fundamental education and counseling may be necessary before a demand for technology is generated in local industry. This Department of Commerce program is based on the concept that technology cannot be transferred effectively from a central Federal agency.

Thus agency policies, at present, are at variance as to what should be done with federally controlled technology and also as to what parts of the transfer process the Government should be active in.

The attitudes of the industrial corporations, which are the principal research and development performers for Federal agencies, can be characterized as favorable to some aspects of the technology transfer activities of the Federal Government and unfavorable or ambivalent to others. Industry applauds Government information systems designed to provide scientific and technological data because they have helped to solve existing problems and helped to avoid duplicative research and development. Industry's preference is for information systems narrowly conceived that provided in-depth coverage of a field or discipline rather than data centers broad in scope that tend toward superficial coverage (see p. 159).

Possible expansion of Government activity or reporting requirements met with disapproval unless limited to data collection and dissemination. Several corporations evinced concern that their commercial technology intermingled with Government contracts would become subject to reporting requirements. Contractors feel that the sophisticated character of NASA technology normally necessitates substantial development costs before it would be useful in the commercial sector.

Some of the same corporations that made these observations also indicated that their Federal research programs and commercial programs overlapped considerably. This would present a difficult problem to anyone trying to trace technology transfer within these firms.

The corporations raise a crucial question: If Government-sponsored technology normally requires additional development before it can become commercially useful and if the cost involved acts as a major constraint on the utilization of this technology for commercial purposes, then should the Federal Government provide further financial support in those cases where additional development costs are justified by high potential benefit?

The transfer of technology from Federal military-space programs to commercial application is intrinsically inefficient compared to directed research and development sponsored for specific purposes by industry. Only the massiveness of the recent Government investment makes the promise of private sector gains possible. This point is important for foreign countries who hope to attain technological maturity. It also means that the surest way to increase technological change is to provide incentives and remove disincentives for all of American industry to make privately funded scientific and engineering efforts.

Further attention to federally generated technology (beyond primary mission applications) may well produce the following contributions to the economy:

Direct transfers of packaged technology, such as airplanes or computers.

Tangible or intangible spinoff applications in other industries.

Multiplier effects of Government procurement in highly technical fields.

Stimulation of basic science via feedback from applications of new technology.

New processes and techniques, new products, and devices to replace former methods and provide capabilities not previously available.

Cost reductions in goods, processing, and services.

Increased availability (and lowered cost) of radical or exotic instruments, equipment, and materials.

Management techniques for complex technological projects and systems.

The means of obtaining these benefits is a vital national issue that needs to be thoroughly studied and discussed by the public and private sectors.

Conclusions

The analysis of information in this report shows the following relationships in technology transfer:

1. Public funds generate about two-thirds of the available technology and the Government has a responsibility to get full benefits from this knowledge.
2. Federally derived technology has appreciable utility to industry and to other public programs at all levels of government. Well documented "second applications" are appearing with increasing frequency.
3. Therefore, Federal Government efforts are warranted in devising and operating programs to make this technology readily available to all users (see p. 58).
4. The private sector innovation rate is affected by a "climate" of which the availability of technology is an important part. Traditional sources of technology need to be expanded beyond the permanent staff capabilities of many firms.
5. Reeducation and counseling as to the technological needs of industry are necessary before strong demands for new information will arise. The Federal Government can logically participate in technical services but local and individual initiative will be most important in recognizing the potential for technology transfer.
6. At the present time, there is no uniform policy or practice among Federal agencies as to technology transfer. The NASA and AEC pursue a central-agency concept of collecting and disseminating technology. The DOD makes no special effort for the transfer of its majority share of Government-sponsored technology. The Office of State Technical Services concentrates on identifying user needs. The clarification of Government responsibilities, including patent policy for R. & D. contracts, is essential to any expanded transfer programs (see pp. 121 and 138).
7. Additional public discussion and formulation of opinion from both private and public sectors is necessary before detailed policy planning can proceed. The lack of "feed back" response from users of new technology makes difficult the evaluation of any particular transfer method. Ongoing Federal programs should be examined more intensively for evidence of acceptance and efficiency.

II. INTRODUCTION—FROM SCIENCE TO SALES

The Senate Select Committee on Small Business has established, in its Subcommittee on Science and Technology, a means of studying the relationships of research and development activities to American business. One of the most intriguing of these interactions is the flow of scientific knowledge from the early stages of conception through invention, innovation, and diffusion to the final result of profits in the free-enterprise system. In order to characterize and understand the complexities in moving from science to sales, the subcommittee has undertaken an extensive investigation of the current policies and practices in dealing with technological information, both in the Federal Government and the private commercial sector. The goal of the study is to assure the maximum utilization of technology from federally sponsored R. & D. programs.

A. Objective of the Report

As a background for the investigation, the Science Policy Research Division of the Legislative Reference Service in the Library of Congress has been asked to prepare this report. The objective is to describe the ingredients of the technology transfer process, the present Federal agency policies, attitudes, and activities, and the relevance of the subject to national economic goals. Through analysis and understanding of existing programs, the Congress should be in a better position to assess the adequacy of present policies and to plan a course of action for the future which will meet the requirements of a society increasingly dependent on science and technology.

President Johnson has said that "the test of our generation will not be the accumulation of knowledge * * * our test will be how well we apply that knowledge for the betterment of mankind." (September 14, 1965, upon signing Public Law 89-182, the State Technical Services Act).

There are methods and techniques in this application which can be studied systematically. The identification and description of business problems in terms of the technology which might be used to solve them is a major factor in application. The process may be speeded up and made more efficient. Both government and industry share a responsibility to develop the optimum system for technology utilization.

B. The Call for Clear Government Policy

The issue of the Government role in technology transfer has been recognized in recent statements by leaders in science, industry, and government. Harvard's Dean Harvey Brooks, Chairman of the National Academy of Science's Committee on Science and Public Policy has called for a Federal policy statement:

> Such a statement might begin with an affirmation that a rapid rate of technological innovation is an important ingredient of economic growth, and that

henceforth Federal agencies engaged in the support or conduct of R. & D. should attempt to shape their policies with due attention to their economic impact—including particularly the horizontal transfer of technology from the immediate purposes of the agency to other purposes and to the civilian economy.[1]

The National Commission on Technology, Automation and Economic Progress concluded that:

> The transfer of technologies developed in Federal laboratories and agencies for industrial and consumer use requires a more forthright and unified Government policy than exists at present.[2]

The U.S. Chamber of Commerce said recently:

> When economic growth is the major concern, industrial innovation, commercialization and the building of proprietorship must be encouraged. This encouragement can be much better accomplished by Federal efforts to relieve the constraints currently inhibiting investment by industry, than by large expenditures in federally sponsored programs.[3]

Dr. Richard Rosenbloom, in his report to the National Planning Association concludes:

> Technical information has become one of the most important factors of production—next to the classical factors of land, labor, capital, and management. This factor must be the concern of a government charged by law with the promotion of conditions favorable to economic growth and the creation of employment opportunities.[4]

President Johnson in transmitting the 16th Annual Report of the National Science Foundation, stated:

> To be fruitful, scientific and technical information must quickly reach those who can use it. As the volume of research results grows, this becomes harder to achieve. But the stakes are well worth the effort. Every increase of 1 percent in the efficiency of our $22 billion public and private research and development programs is worth $220 million per year. The Foundation will, therefore, institute new programs to devise improved systems for handling scientific information, and will work with other Government agencies to establish standards for Federal technical information programs.[4a]

As yet, however, no one has presented detailed proposals for a governmentwide policy. Policies tend to evolve, whether by design or in a backward fashion, from practice. A planned policy has the advantage of considering all the elements of a system and their interrelations. Policy is a prime tool of management, and technology is a national resource to be wisely managed. The subcommittee's investigation will examine present policies and practices to create a sound basis for improved policies for technology transfer.

C. Scope and Methodology

The present study was announced to the Senate on October 17, 1966. Senator Jennings Randolph said:

> Today, I call attention to a study that our subcommittee has initiated and which we believe will be of far-reaching benefit to small businesses and to the continuation of dynamic national economic growth.
>
> The subcommittee is making a comprehensive study of the transfer and utilization of scientific and engineering knowledge which has been gained as a result of

[1] Before a conference on technology transfer and innovation, The National Planning Association, Washington, D.C., May 1966.

[2] "Technology and the American Economy," Report of the National Commission on Technology, Automation and Economic Progress, and Appendixes, vols. I through VI, February 1966, Government Printing Office, Washington, D.C.

[3] "Criteria for Federal Support of Research and Development," U.S. Chamber of Commerce, Washington, D.C., 1965.

[4] Rosenbloom, Richard S. Technology Transfer—Process and Policy, July 1965, National Planning Association, Washington, D.C.

[4a] *Congressional Record*, Apr. 6, 1967, p. H3648.

the vast Federal research and development programs. The question we will endeavor to answer is: How best can such new technology be most expeditiously and efficiently woven into the fabric of industry and thus into the products and services available to the American consumer?

As we know, the road between basic scientific research and consumer sales is long and extremely complicated. When there is an intervening conversion of scientific knowledge into purposes other than that for which the research was principally intended, there is an added dimension of difficulty.[5]

This report is intended to provide a background for subsequent public hearings which will aid in establishing future policies for Federal technology transfer. The framework within which science and technology interact with economic and social factors is described. The process of technology transfer has been the subject of considerable study in recent years. A summary of the generally accepted points of view is included as well as the conflicting interpretations. Technology transfer is related to other factors in Federal research and development funding including patent policy, distortions of total scientific effort and the private sector performance. The report identifies and analyzes issues for further consideration in public hearings.

The report concentrates on the transfer to the business community of technology resulting from large Federal R. & D. programs. It also considers the broader context of transferring technology regardless of source to serve secondary needs in other governmental programs and in industry. Ultimately, the subcommittee wishes to suggest policies which will assure that the knowledge derived from federally funded R. & D. is utilized to the fullest possible extent, not only in the private consumer oriented economy, but for the benefit of other public programs.

The question of mechanisms for the handling of scientific and technical information is not a major concern of this study although it is recognized that an adequate system *must* exist if technology transfer is to succeed. The allocation of scientific resources to avoid gaps or overlaps and to serve public and private purposes most efficiently is an important and continuing interest of the Congress but is not examined extensively in this report.

D. Some Definitions

Technology is knowledge about the industrial arts; it is the way science is used to benefit society. In the course of scientific and engineering activity, ideas are subjected to experiment and concepts become tested theories. Techniques and devices are developed and demonstrated. This experience and lore, the ways of doing things, the elements of information and experience, are a part of technology. The models and procedures of the research laboratory, and the inventions and imaginative solutions to problems, form bits and pieces of technology which can be fitted into mosaics of new products, processes, and services.

Technology transfer is the use of knowledge to serve a purpose other than the one for which the R. & D. was undertaken. Such additional beneficial application is desirable because the cost of the research has either already been written off, or thus may be spread over a broader

[5] Congressional Record, October 17, 1966, p. 26199.

77-217 O—67——2

base of profit return. But the second utilization most probably will occur in a situation removed in time and place from the origin of the technology. So collection, packaging, and transportation charges constitute a proper cost to the system, whether the knowledge is provided gratis or not. Technology transfer involves an exchange process where money, time, effort, and risk are tendered for new facts.

A current and typical example of the direct transfer of Government-sponsored technology is a news story which appeared in February 1967:

GAS FUEL CELL PLANNED AS ELECTRIC COMPETITOR

CLEVELAND (UPI).—The gas industry says it will take a page from space technology to develop a natural gas fuel cell it hopes will edge the electrical power industry out of competition.

East Ohio Gas Co., its parent company, Consolidated Natural Gas, and 20 other gas utilities announced a 20-million, three-year research contract has been awarded to Pratt and Whitney Aircraft, a division of the United Aircraft Corp.

The fuel cell could be compared to a storage battery that never needs recharging, according to a spokesman. He said it should generate electricity for all needs.

"We are building on experience Pratt and Whitney has gained in fuel cell power plants in the government's space exploration program," said G. J. Thankersley, East Ohio Gas President.[6]

Describing the movement of technology is made convenient by imagining a three dimensional transfer space.

Technology is transferred *vertically* within a development program when an idea evolves from discovery, through invention, through prototypes, and through engineering to an operational system. The new knowledge flows from the research laboratory to substantiating tests, development, and evaluation, and finally into manufacturing, processing, or service. The vertical transfer involves many persons and organizations even within one firm.

Technology is transferred *horizontally* when knowledge moves from one field of science or industrial sector to another. Horizontal transfer is characterized by diffusion of inventions and techniques throughout the economy. Diffusion can occur at any stage of the vertical process, from new idea to completed development. Therefore, the source of knowledge for technology transfer is not only the reserach laboratory but wherever ingenuity is manifested.

Eric Jantsch, consultant to the Organization for Economic Cooperation and Development, has suggested the completion of the "transfer space" by the addition of a third dimension.[7] This would represent the interaction of technology with nontechnological factors such as marketing, social institutions, current events, and economics (see p. 65).

Historically, the organization of our economy has promoted *vertical* technology transfer. Research and development programs are planned with a goal and a timetable in mind. Except for truly basic and fundamental research, personnel are alert to application requirements. New knowledge is efficiently tailored and developed to meet the mission needs. *Horizontal* transfer has occurred haphazardly and slowly via movement of people, technical literature, professional meetings, marketing, patents, and, of course, the entrepreneur. It requires imaginative, energetic receptors who can perceive otherwise hidden relevance and promise.

[6] Washington Star, Feb. 9, 1967.
[7] Jantsch, Eric, Technological Forecasting in Perspective, Organization for Economic Cooperation and Development, DAS/SPR/66.12, October 1966, Paris, p. 18.

This study is primarily concerned with *horizontal* transfer from Federal R. & D. performers to other concerns and across industry boundaries. Nevertheless, the total, three-dimensional movement of scientific knowledge is recognized as the framework for ultimate gains to society.

Potentially useful new technology. The "gray area" of information between scientific facts and hypotheses, and patentable inventions should contain useful bits and pieces of technical knowledge. Because of the reporting requirement placed on contractors by NASA, the agency has had to define reportable new technology:

> A "reportable item" is defined by the Space Act as "any invention, discovery, improvement or innovation," whether or not patentable, that is conceived or first reduced to practice in the performance of work under the contract. Items include, but are not limited to . . . "any new or improved techniques, products, devices, materials, processes, compositions, systems, machines, apparatuses, articles, fixtures, tools, methods, or scientific data." Scientific and technical computer programs, for example, are reportable items.
>
> You should concentrate on reporting—
>
> Any invention that reasonably appears to be patentable.
>
> Any other invention, innovation, improvement, or discovery for which there may be use in the general economy.[8]

The amount of this technology is estimated by NASA to be from one-half to one reportable item per man-year of R. & D. effort. It is estimated that 500,000 scientists and engineers do research and development work and about two-thirds of the total R. & D. in the United States is funded by the Government. Thus, on a rough basis, 170,000 to 340,000 reportable items subject to Government processing would be generated each year—a substantial task in information handling. The current NASA program is issuing about 3,000 "flash sheets" per year which represent screened items deemed worth disseminating. These figures may be compared with the estimate of 2 million primary scientific articles appearing in 45,000 periodicals each year.

Federally controlled technology. The bulk of recent research and development in the United States has been sponsored by Federal agencies through grants and contracts. The nature of the work and the field of science are dictated by national goals which are converted to agency missions. The R. & D. has been guided by Government monitors. The new technology which results has been paid for with public funds. It is used or discarded or preserved largely under the authority of the agency although the originating laboratory can initiate certain dissemination actions. It may be retained by the performer as an unpublished, unreported trade secret. The technology is Government controlled, not in the sense of undue restriction but because justification for the R. & D. lies in the agency mission as does responsibility for any subsequent collection or processing of the new technology.

Without some overt action on the part of the Government, it is very difficult for any interested organizations (other than the performing laboratory) to acquire the technology.

[8] Management Guidelines for New Technology Reporting to NASA, NHB 2170.1, October 1966, p. 5.

E. Necessity Is the Mother of Invention

The literature concerning technology transfer is extensive.[9] Articles, testimony, reports, theses, and books appear every month to analyze or interpret the complexities of using new technical information to obtain economic benefits. It is somewhat disconcerting to realize that the sum and substance of most of this scholarly treatment was first voiced by Plato in "The Republic" about 400 years before Christ: "Necessity, who is the mother of invention."

Need, recognized and felt, is a driving force for the acquisition of all the knowledge and other resources for its fulfillment. New scientific facts themselves will seldom be sufficient to create economic growth. And yet invention must have other forebearers beside necessity if it is to amount to anything more than an incremental advance from the ordinary. The inventor will do better if he has ready access to the greatest possible amount of information. Without straining the metaphor, necessity becomes more fertile in a rich environment of facts, data, and experience.

Technology transfer works to improve the rate and quality of innovation and invention.

The test of an invention is whether it works and is profitable, not whether it is understood. But the impact and value of inventions is likely to be greater when the underlying science is established. And as civilization becomes more complex, inventions which truly contribute to progress are dependent on intricate technical relationships. Inventions in the 18th and 19th centuries were made largely without understanding. For example, iron and steel making developed without knowledge of the relationship of small changes in chemical composition to the strength and properties of the finished metal. Since about 1920, research and development specifically directed toward product or process improvement and invention has become the organizing influence on technology. Industry has recognized that investment in scientific activity will allow the design and tailoring of new products and processes toward predetermined goals. Science and engineering effort is an efficient and predictable mechanism for achieving industrial progress.

In the future it seems likely that technology transfer will become a complement to planned R. & D. as a resource for invention. Technology already created in another field may be as new to the application engineer, inventor, or innovator as the knowledge from directed experiments in his own laboratory. If the transferred technology can be selected, packaged, and transported as cheaply as new knowledge can be created, it becomes a competitive source of invention. The large amount of accumulated technology ready for transfer compared with the amount of current directed R. & D. is a recent occurrence. The impact of technology transfer on invention and innovation has not yet had time to be effective. Transferred knowledge could lead to a future acceleration and improvement in innovation which would be as great as the applied science impact of the past 50 years.

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[9] An annotated bibliography on technological change, transferring military and space technology to industry, the environment for innovation, and the economic effect of technology transfer has been prepared recently for the Office of State Technical Services by the Clearinghouse for Federal Scientific and Technical Information: Technology Transfer and Innovation: A Guide to the Literature, August 1966, PB-170-991, STS 104.

III. QUESTIONS BEFORE THE CONGRESS

The report suggests the following questions for further study in public hearings or discussion. They are presented in no particular order of importance nor do they carry equal weight in influencing future policy planning for technology transfer. The questions are not all within the jurisdiction of the Select Committee on Small Business and it is obvious that broad consideration by the Congress will be required before the issue is resolved.

A. Economic growth

1. Is the Nation satisfied with the present rate and direction of economic growth?

2. Is technological change occurring at an appropriate rate? What information is needed to know the desirable rate? What information is needed to show the net contribution of new technology to economic growth?

3. Is new technology available to industry of the right sort for the desired growth rate and direction?

4. Are nontechnological problems so dominant in economic growth that technology availability is relatively unimportant?

5. Is the typical small manufacturer capable of assimilating transferred technology? What are the incentives and disincentives for innovation?

6. To what extent is the future of the small business concept in the United States dependent on the ability of these firms to absorb and use new technology?

7. Which industries are highly dependent on new technology?

B. Federal sponsorship of R. & D.

1. Have Federal distortions of the total United States R. & D. picture caused civilian industry to have less technology at its disposal than is desirable?

2. Are military, atomic, and space R. & D. the only Federal technologies which should be the subject of overt transfer efforts?

3. Should Federal R. & D. performers (intramural or private sector) take technology beyond mission requirements to a stage where it is more readily transferable?

C. Locating technology for transfer

1. Should new technology reporting clauses be in all Federal contracts?

2. How should reportable item location costs be paid for?

3. Should Government personnel be responsible for locating transferable technology in contractor laboratories? In Federal contract research centers?

4. How can contact between the originator and the user be established and paid for? Should the inventor become the transfer agent? How?

5. Should a professional scientist or engineer feel as much obligation to report technological items as he does for scientific data? How can a reward system be established to motivate this action?

D. Processing technology for transfer

1. Should processing be centralized? In one agency? In one location? Regionally?

2. How can technology be integrated into an evolving Federal scientific information system? Into the present system?

3. What are the pros and cons of a private processing system?

4. Is the retrieval process now so complicated and time consuming that accumulated technology is not an attractive source of ideas for innovators?

E. Dissemination of technology

1. Are regional centers for specially designed geographical areas preferable to one in each State?

2. Can industrial fees be expected to completely support dissemination efforts? What parts of the process should industry pay for?

3. Is the bottleneck in applying new technology in the business sector? Is it in the lack of proprietary protection given by Federal policies for nonexclusive access?

4. How much aid in need identification and in applying Federal technology should the Government provide to individual firms?

5. Should small business be the special recipient of transferred technology? Via an SBA program?

F. Current Federal transfer programs

1. Is there sufficient research on the process—"replacing anecdotes with facts"?

2. Are there meaningful measures of the success of agency experimental programs? Over what timespan?

3. Should the AEC, NASA, and Department of Commerce programs be coördinated more closely? All put under one "capping agency" management?

4. Is the DOD policy toward technology transfer inconsistent with national objectives, stated or not?

5. What group, within the executive branch, should emerge as the point of contact for business in acquiring new technology?

6. What should the "White House superstructure for science and technology" be responsible for in technology transfer?

7. Could a comprehensive private sector transfer program take over some or all of the functions following collection of the information?

8. Does the uncertainty of annual Federal funding inhibit Government transfer programs?

G. Relevance of federally controlled technology

1. How does the relevance of this technology to civilian uses vary among Government programs?

2. Can relevancy be judged at the point of origin?

3. Is there enough obvious relevancy to pay for special identification work at the originating laboratory or should the processing system accept unevaluated items?

4. Should the Government make efforts to pull together the available technology which might apply to evolving public needs (i.e., air pollution, mass transportation, etc.)?

H. Nongovernment attitudes

1. Does industry, as a whole, evidence a desire for increased Federal transfer efforts? Are there certain industrial segments which need Federal assistance and are they important enough to justify a comprehensive program?

2. What would be the consequences of *not* pursuing a Federal technology transfer program?

3. How would unrestricted dissemination of new technology conflict with the U.S. position in international trade? Should other countries be able to tap into a privately operated system?

Suggested Transfer Concepts

During the preparation of this report, a number of concepts have been suggested which would apply to part or all of the technology transfer process. Some may be supplementary to present programs while others are possible alternatives. In order to provide stimulus for further discussion they are summarized below. No particular merit is attached to any of the ideas at this time although some are clearly worth exploration in detail.

1. Sustaining grants for local transfer activities by nongovernment organizations such as the independent not-for-profit research institutes.

2. A Government agency called the Institute for Advanced Technology to perform and/or contract for the development and demonstration of promising innovations for selected civilian purposes.

3. Greater support by all agencies for an expansion of the services of the Clearinghouse for Federal Scientific and Technical Information. This includes the prompt and complete release of all possible technical documents. Addition of personnel for preparation of selected bibliographies and survey reports is suggested.

4. Use of the Federal Contract Research Centers as technology transfer institutions, and as applied research or demonstration laboratories.

5. Special packaging for dissemination of federally controlled technology which may be applicable to newly recognized public needs (e.g., pollution abatement or crime prevention).

6. Making the Department of Commerce the Federal focal point for new technologically based enterprises.

7. A "middle ground" knowledge-transformation industry may develop to provide transfer services for a profit.

8. Every firm, large or small, which needs new technical information should establish a "technology prospector" within management to serve as a transfer contact and as an active seeker of Federal services.

9. A "Project Foresight" to expand Federal R. & D. beyond immediate missions to refine and develop technology for possible commercial application.

10. Providing more high-risk capital to innovators through the Small Business Administration.

11. A National Library for Science and Technology with research and reference services.

12. The use of Federal Government procurement standards to provide a market for innovations.

13. Establishing a uniform policy in all agencies for the absolute necessity to transfer scientific and technical information.

14. An industrial extension service patterned after the agricultural extension activity.

15. Additional emphasis for the Science Information Exchange (Smithsonian Institution) and the National Referral Center (Library of Congress).

16. A centralized monitoring and coordinating office to supervise the transfer activities of all agencies.

17. A training program for transfer agents, trainees to come from industry and government.

18. A White House conference on "Understanding and Improving the Environment for Technological Innovation."

19. Making Federal R. & D. facilities available at reasonable cost to individual and small business innovators.

20. Providing the services of Federal laboratory scientists and engineers as consultants or transfer agents for their own ideas.

21. Providing Government support for professional journals which will judge the quality, relevance and utility of new technology and which will publish such material for technology transfer purposes.

IV. CONGRESSIONAL INTEREST IN TECHNOLOGY AND THE ECONOMY

The study of which this report is a part represents the first comprehensive look at technology transfer, per se, which has been undertaken by the Congress. However, there has been a continuing cognizance of the importance of science and technology to the economy extending back to the post-World War II years. Technological change affects the rate of economic growth and the composition of economic strength. Governmental actions which impinge on technological change include tax policy, antitrust laws, patent procedures, new investment influences, tariff agreements and many other incentives or disincentives to innovation. Appropriate congressional committees have exercised an oversight role in all of these areas of interaction and continue to do so.

One of the most important Federal Government policies for technological change has to do with its own involvement in scientific research and development. Although these funds are clearly authorized and appropriated for support to agency missions, the Congress has recognized their impact on resources and on the economy. The following paragraphs present some highlights of recent reviews by the legislative branch.

A. The Senate Select Committee on Small Business, 1963 Hearings

In 1963, during May, June, and December, then Senator Hubert Humphrey held hearings on "The Role and Effect of Technology in the Nation's Economy."[10] Now, 4 years later, these hearings and the appendixes of relevant material still constitute an accurate and rather complete discussion of the subject. The central issue is one of deciding the Government responsibilities in its domination of science and engineering activity.

> Senator Humphrey. * * * I think the most important point that we seek to analyze or study is the effect of these R & D contracts or the effect of this great research upsurge upon the total economy.[11]

*   *   *   *   *   *   *

The topics covered included: the supply of scientific and engineering manpower; the effect of R. & D. on the universities; the effect of technology on unemployment; the statistical correlation of R. & D. expenditures with gross national product, Federal budgets, and the growth of certain industrial sectors; the distribution of R. & D. effort between military-space programs and civilian commercial activities; the geographical distribution of R. & D.; the problems of small business in participating in R. & D.; the creation of centers of excellence; and foreign R. & D. programs.

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[10] U.S. Congress. Senate. Select Committee on Small Business. The Role and Effect of Technology in the Nation's Economy. A review of the Effect of Government Research and Development on Economic Growth. 88th Cong., 1st sess. (pts. 1-6).
[11] Ibid., p. 22.

1. TECHNOLOGY TRANSFER

The technology transfer issue emerged in terms of information dissemination, the "fallout" possibilities, and the "climate" for innovation and diffusion of new products and processes in industry. Dr. Jerome B. Wiesner, then Director of the Office of Science and Technology said:[12]

> I believe that our past and present environment reflect policies and decision-making practices which may often inhibit the fullest commercial use of technology already available in the research laboratory. I am suggesting, therefore, that the problem faced by industry and Government—and by your committee in these hearings—is not only one of guiding allocation of scientific and technological resources so as to create new and needed knowledge, but equally one of removing obstacles to the commercial utilization of such knowledge.

The possibility of direct application of devices or techniques developed in Government, defense, space, or atomic energy programs to the civilian economy ("spinoff," "fallout," "spillover") was shown to be remote.[13] This is because of the differences in problems and needs between the two areas; so it is not surprising that the solutions for one would not often fit the other. Occasional specific instances of direct transfer can be identified but these are not of sufficient frequency to contribute to the original justification for the government work. Even within a single company, transfers are rare between divisions manufacturing civilian goods and others engaged in government work.

Less direct or less tangible transfers were also infrequent, according to the testimony. It was suggested that too short a time had elapsed for much of the military-space technology to show up in civilian goods and services.

The contrast between successful applications resulting from technology transfer and those from conventional research toward stated goals was described by Mr. John H. Rubel, then Assistant Secretary of Defense:

> * * * the deliberate direct application of science and technology to known tasks is by far the most efficient and direct way to accomplish those known tasks.[14]

2. INSTITUTIONS INVOLVED

Various parts of the sequence of events leading from science to sales are usually separated in time, and as to the institution which holds the technology. Universities are the source of much scientific knowledge, but are often uninformed as to the current needs of business. Research in one segment of industry may have no clear transportation mechanism into another where it would be useful. A greater emphasis was called for in applied research institutes to tie ideas to needs. Dr. Jesse Hobson (then of Stanford Research Institute) said:

> We have a spectrum now, I think, of the institution of higher education, the institution of very advanced research, the institution of applied research and, finally, the ultimate user of all of this technology. If some of these pieces are missing, then we are not going to have a successful transition of science and technology into profits and economic development.[15]

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[12] Ibid., p. 215.
[13] Ibid., pp. 22–30.
[14] Ibid., p. 23.
[15] Ibid., p. 57.

Senator Humphrey * * * it is a matter of growing concern—and it surely should be—that vast numbers of people who are highly trained, extremely able in terms of intellectual capacity, are living in and working in an environment which is removed from commercial life.[16]

Dr. Richard S. Morse, former Assistant Secretary of the Army said:

* * * We have a large segment of companies in our country who have never known anything but operating under the Federal budget and know essentially nothing about a competitive commercial business.[17]

The difficulty of the universities' making a direct contribution to industrial technology was discussed by Dr. James R. Killian of the Massachusetts Institute of Technology:

Dr. KILLIAN. I don't think that universities in their function of conducting basic research can make, necessarily, a direct contribution to the development of the civilian consumer-oriented part of the economy, but I think they can, indirectly, through the people they train and through the new technology that comes out of their basic research, make a very great contribution here. I think it is of the utmost importance that we have a relationship between our universities and the industrial community that makes available new ideas coming out of basic research rapidly that industry can employ to the strengthening of their competitive consumer developments.

I have a personal feeling that we may be in a situation now where the civilian consumer part of the economy is not having the application of manpower and innovation that it really needs to push ahead, with some brilliant exceptions.[18]

The conclusion from this testimony was that certain U.S. industries were lagging in applying new technology. One of the principal reasons was that such firms were not directly involved in research and development. The applied research institutions seemed to have an unfulfilled role in transferring knowledge to unsophisticated firms. The government was seen to have some responsibility in assisting the transfer.

3. INFORMATION PROCESSING

These hearings established the need for improvement in Federa scientific and technical information handling. Reports from R. & D programs were found to be often incomplete, disorganized, out of date, and of low technical quality. No systematic dissemination system, or means of rapid access, was available to other researchers. These conditions contributed to unnecessary duplication of research and made secondary utilization of the knowledge more difficult.

Senator HUMPHREY: * * * this is why I believe the coordination of information through the establishment of regional information centers on all of these new scientific, technological developments is so essential. The truth is that we have many examples of where there is a delayed application of a machine, an appliance, or even a scientific principle.

So, the basic principles are pretty generally known and it takes a good deal of time to get the adaptation or the utilization of the principle in a practical realm.

I want to say again that, with all the money we are spending on research and development, it is still quite shocking to me to see how little attention is being given to the proper dissemination of the information that is not classified.[19]

4. THE AGRICULTURE ANALOGY

At the time of the 1963 Senate Select Committee on Small Business hearings, the Department of Commerce was embarking on its short-lived program of civilian industrial technology. (See p. 23.) Dr.

[16] Ibid., p. 203.
[17] Ibid., p. 196.
[18] Ibid., p. 310.
[19] Ibid., p. 25.

Herbert Hollomon, Assistant Secretary of Commerce for Science and Technology, explained what it was hoped would be accomplished:

For example: Additional support for the technology in a local area, at the university, let's say in textiles and apparel, or the building and construction industries, or the food processing industries, or the various other industries that are crucial to the development of our economy. We would hope to do this by stimulating industrial research associations to provide part of the funds, which the Federal Government would supplement, and we also are planning to support what is equivalent to an extension-kind of program to bring technology to local industry on a local level and connect the university that provides the technical resources to the industry of the region.

In both cases, I believe that the decisions as to how this is to be done should be made locally by people who know what the problems are.

But the stimulation and some of the funds should be made available by the Federal Government, in no case to provide support for an individual firm, but in all cases to try to stimulate local initiatives, just as we did in the earlier times with respect to agriculture.

Senator HUMPHREY. That is the best example that we have of applied technology.

Mr. HOLLOMON. It is the best example.

Senator HUMPHREY. And by the way, agriculture has the best record of increased productivity and improved technological efficiency. Industry looks like a cripple compared to agriculture.

Mr. HOLLOMON. People frequently confuse some of the difficulties, that is, the fact that we provide subsidies, with the great benefits in advancing agricultural technology.

These two things are not necessarily connected. The important point here is that the improvement in productivity in agriculture came about through a combination effort among the farmer, the university, the industry, the Federal and local governments. It was one of the most effective mechanisms that I believe we have ever created for the improvement and utilization of technology in our economy.[20]

At the same time, it was recognized that agricultural technology was common to geographical localities whereas each region would contain many diverse industries so that the information dissemination problem was much more complicated (see p. 21).

5. THE NASA PROGRAM

Administrator James E. Webb of NASA described the rationale and beginning of a technology utilization program to fulfill a part of the space agency charter:

Mr. WEBB. In the area of particular interest to this subcommittee; namely, the utilization of science and technology in the economy of the country, we have vigorously sought those people best qualified to find new and enervative [sic] ways for technology and the basic things resulting from our research which make for economic advance and encourage people to pick up and use this technology.

Among other things we asked the Midwest Research Institute in Kansas City, which has for 18 years been doing research for private industry and has done research for some 800 or 900 companies, to go to our laboratories, look over the work that was being done in the space program, and from their long experience with private industry, try to identify those things that could be most useful to private industry.

* * * * * * *

Now, the Midwest Research Institute did identify about 200 items that they felt sure from this long experience with industry would be useful. Fifty of these have in a fairly organized way been exposed throughout the country to industrial people, and a good many of them have started industrialized thinking about new ways and new processes.

In a few dramatic instances, considerable success has been had through this process. But it is an experimental method. I am not at all sure this is something

[20] Ibid., pp. 186–187.

that a Government agency would want to do over a long period of time, but it was one way to get started with the legal requirement that we endeavor to get applications of the products of our research.

Now, in another instance we have started a pilot model of considerable interest at the University of Indiana. We have gone there to the business school and they have organized an effort in which they take all of our technical reports and put them into a computer storage system, and then they constantly match against this computer storage of technical information the needs of 29 different companies that pay $45,000 a year to have their needs matched against this computer storage system of technical information coming out of the NASA program.

Now, this has only been in existence a relatively short time. In the last 3 or 4 months we are beginning to see some extremely interesting results of this. One new industry is being started out there, a small industry based on a process that they identified out of this computer process.[21]

6. CORRELATING R. & D. EXPENDITURE WITH ECONOMIC GROWTH

The appendices to the hearings included the proceedings of a symposium held by the National Security Industrial Association, "The Impact of Government Research and Development Expenditures on Industrial Growth," March 13–14, 1963.[22]

One of the areas of agreement among the participants was the difficulty of establishing cause and effect relationships between R. & D. investment and economic growth. The time delay between research discoveries and the entry of a product or process into the market means that current R. & D. expenditures do not affect current growth. The many factors aside from technology which affect industrial change may obscure the relationship. These include communication and transfer problems since the probability is low that the original researcher will also be the innovator and applier of the technology.

Reducing the time delay is the primary means of increasing the impact of science and technology on economic growth. More must be known about the transfer process before it can be speeded up, according to the symposium speakers. A clearer understanding of innovation is necessary for an enhanced benefit from industry funded R. & D. as well as for transfer from Federal programs.

Research managers have reacted to the challenge for justification of their expenditures from economists, politicians, and the public. The concept is well accepted that scientific activity makes major contributions to industrial growth, national security, and public purposes. But the quantification of the contribution fails because of the intangible nature of knowledge.

7. BARRIERS TO TECHNOLOGICAL CHANGE

There are deep inhibitions to change in industry. (See p. 58.) Innovation may mean the premature obsolescence of capital equipment. Management may not be equipped to operate in new markets. The functions of government may impede risk-taking and reduce the profit motivation for change. The natural human tendency to maintain the status quo runs counter to the development of new technology. Thus, many changes come from invasion of an industry by a new company. The overall economy is benefited as a result but some individual firms may suffer. Entire industries disappear or are weakened as a

[21] Ibid., pp. 358–359.
[22] Ibid., p. 379.

result of new technology.[23] The identification and removal of these barriers will come from a better understanding of the environment of industrial growth.

The 1963 hearings demonstrated the difficulty of studying innovation but also showed the opportunities for improving the Nation's economic health if clearer relationships could be established. The present study is a logical outgrowth of the previous testimony before the Senate Select Committee on Small Business.

B. The State Technical Services Act of 1965

The Congress considered the technology transfer problem at some length in connection with the passage of Public Law 89–182, The State Technical Services Act of 1965, signed by President Johnson on October 14, 1965. Prepared by the Department of Commerce after a considerable period of discussion within and without the Government, the act focused on local planning and action to aid business and industry in acquiring new technology. Details of the act are presented on p. 103 in connection with a discussion of the resulting Office of State Technical Services.

The Economic Report of the President for 1964 stated:

> The Federal Government provides major support for the research and development which underlie our striking technological advances. In the past much of our research and development has been connected with national defense. Now, as military outlays level off, we face
> —a challenge to apply the Nation's growing scientific and engineering resources to new socially profitable uses;
> —an opportunity to accelerate the technological progress of our civilian industries.
>
> The Federal Government should join with private business and our universities in speeding the development and spread of new technology. I have directed the Department of Commerce to explore new ways to accomplish this.[24]

Hearings on the bill were held in June of 1965 in both the House and Senate.[25] [26]

The thrust of the testimony was that many industries, often those which are small and do not have technical staffs, are lagging in the application of new technology. The bill proposed the mechanism of a university extension service to assist potential users in identifying their problems and in locating a source of information or further advice. One of the justifications for the emphasis on universities was that their participation would bring a closer appreciation of the problems of regional industry with consequent improvement of the education of future employees for these businesses. Some States had already begun programs through engineering experiment stations. The not-for-profit research institute had generated local interest wherever they were established. This experience suggested that matching Federal funds would encourage the establishment and expansion of technology efforts in each State. The public moneys thus spent would be returned in increased industrial growth, high employment, and new businesses. The improvement would be equitable geographically, an aspect of R. & D. activity which was important to the Congress.

[23] Ibid., p. 784.
[24] Economic Report of the President, 1964, p. 14.
[25] U.S. Congress. House. Committee on Interstate and Foreign Commerce. Hearings before the Subcommittee on Commerce and Finance on H.R. 3420. 89th Cong., 1st sess., 1965.
[26] U.S. Congress. Senate. Hearings before the Committee on Commerce on S. 949 and S. 2083. 89th Cong., 1st sess., 1965.

The hearings were not concerned substantially with the source of the technology to be transferred, although the Federal R. & D. programs were mentioned as a preponderant reservoir. The act clearly did not include the Federal sponsorship of research for civilian industrial applications. The service intended was limited to an early counseling stage and was intended not to interfere with private enterprise consulting and development firms.

The Congress reacted favorably to the analogy between the State Technical Services concept and the 100-year old Land Grant College participation in agricultural technology dissemination. This, coupled with the matching fund emphasis on local initiative, provided the bill with wide support. Appropriations hearings are discussed on p. 24.

C. The Office of Technology Utilization, NASA Authorizations

The annual authorization hearings for the NASA budget give the House and Senate Space Committees an opportunity to review the administratively created Office of Technology Utilization (see p. 18). The Independent Offices Appropriations Subcommittees also hear testimony on this activity which is based on an interpretation of section 203(a)(3) of the National Aeronautics and Space Act of 1958, Public Law 85–568, that NASA: "shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." This is accomplished by a relatively small group in NASA headquarters and field stations which concentrates on the identification, reporting, processing, and dissemination of innovations by NASA and contractor employees.

Prior to fiscal year 1964, the program was a part of a NASA Office of Applications. In 1963, the Office of Technology Utilization was established. Congressional response was favorable to the concept but several areas of concern were apparent from the start. These were:

a. Should there be one overall Government program to disseminate information to business?

b. How much encouragement should business need if the knowledge was really worthwhile?

c. How could all regions of the country obtain equal benefits from only a few dissemination centers? [27] [28]

The NASA effort has as a major purpose, the identifying of bits and pieces of technology from the space program, and the Technology Utilization officials testified that this part of the process could not be handled by another agency. The experimental dissemination centers began to charge fees to industry for their services as a means of measuring the value of the technology. The goal of a self-sustaining operation was enunciated. The number of dissemination centers has increased from year to year.[29] [30]

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[27] U.S. Congress. House. Committee on Science and Astronautics. Hearings before the Subcommittee on Applications and Tracking and Data Acquisition on H.R. 5466. 88th Cong., first sess., pp. 3430–3449.

[28] U.S. Congress. Senate. Hearings before the Committee on Aeronautical and Space Sciences, on S. 1245. Pt. 1. 88th Cong., first sess., pp. 7, 10.

[29] U.S. Congress. House. Hearings. Committee on Science and Astronautics. 1965. 1965 NASA Authorization. 88th Cong., 2d sess. Pt. 3: pp. 1609–1622. Pt. 4: pp. 2163–2224, 2810–2813.

[30] U.S. Congress. Senate. Hearings before the Committee on Aeronautical and Space Sciences, on S. 2446. Pt. 2. 88th Cong., 2d sess., p. 417.

At the early stages of the technology utilization program there was a tendency for NASA to highlight specific products or techniques of the "spin off" type. Critics were quick to point out that these instances were rather rare and often confounded by doubt as to the actual origin of the technology—whether Government sponsored or not. In more recent years, NASA has described the activity as an experimental program to find better methods for transferring technology.[31] [32] Congressional enthusiasm for the program has grown along with the understanding that results would only begin to build up in number after several years had gone by.

The usefulness of the regional dissemination centers to business was explored by a poll of subscribers to the Aerospace Research Applications Center at Indiana University conducted by Representative John W. Wydler of the House Science and Astronautics Committee. The results, in part, were:

> Reading and analyzing the letters received was somewhat depressing in terms of the $15.464 million that have been programed and funded through fiscal year 1966. Out of 71 replies received, only 10 could be described as enthusiastically in favor of the NASA programs to which they subscribe. These were the 10 which said they had derived some kind of tangible return (i.e., in terms of paying for their subscription price, etc.) from their association with the various centers. Such disappointment must be tempered by the relative success of this program when compared with some recent ones that have spent billions of dollars with little or no benefit to the public. The difference can be accounted for by the quality and effort of NASA personnel.
>
> One interesting fact was the high degree of success reported by small businessmen who subscribed to the programs. All of them commented that the availability of advanced NASA research material and information was invaluable, being as each of their firms is too small to maintain its own research development department. These small businessmen constituted fully half of those 10 reporting financial gain.
>
> Fifty-one out of seventy-one said that the program was worthwhile, but 41 of those offered reservations: these included nonapplicability of center-provided information, difficulty in learning proper use of the programs, a desire to have the scope of it expanded, and, finally, a number of individual complaints regarding specific incidents which made utilization of the NASA-sponsored services difficult.[33]

The close relationship of the NASA program to the Office of State Technical Services was discussed in the 1966 authorization hearings (see p. 147). The report of the House committee stated:

> There is an obvious similarity of purpose between the NASA program and that of the Office of State Technical Service in the Department of Commerce resulting from the State Technical Services Act of 1965. These programs should be complimentary rather than duplicatory. Therefore NASA is directed to report to the committee by January 1, 1967, on means of coordination and the extent of cooperative activities that have been carried out by the two agencies in calendar year 1966.[34]

Funding for the technology utilization program has been provided at essentially the level requested by the administration, rising from $3.5 million in fiscal year 1964 to $5 million in fiscal year 1967. The fiscal year 1968 request is for $5 million. These funds do not include the cost of new technology offices at field centers nor the costs incurred by contractors for administration of the reporting requirement.

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[31] U.S. Congress. House. Committee on Science and Astronautics. Hearings before the Subcommittee on Advanced Research and Technology, on H.R. 3730. 89th Cong., 1st sess., pt. 4, pp. 89–101.

[32] U.S. Congress. Senate. Hearings before the Committee on Aeronautical and Space Sciences, on S. 927. 89th Cong., 1st sess., p. 1000.

[33] U.S. Congress. House. Committee on Science and Astronautics. Hearings before the Subcommittee on Advanced Research and Technology on H.R. 12718. 89th Cong., 2d sess., pt. 4, pp. 634–666.

[34] Authorizing Appropriations to the National Aeronautics and Space Administration, House Rept. 1441, Apr. 20, 1966, p. 105.

D. The Atomic Energy Commission

The Joint Committee on Atomic Energy has been concerned with the application of nuclear technology to civilian purposes from its inception. The entire civilian power reactor program is an example of Federal development of a technology intended to move eventually under the control of the private sector. Isotope applications have been found in a great variety of industries, a particularized example of the AEC approach to the problem.

More recently the identification and dissemination of non-nuclear technology which is developed under AEC programs has been recognized as a responsibility (see p. 129):

Representative Anderson. You spoke on page 22 of the efforts that are being made to identify AEC nonnuclear technological development and to encourage their industrial use.

Dr. Seaborg. Yes.

Representative Anderson. Would this extend to including manufacture of actual hardware in AEC facilities?

Dr. Seaborg. No; I was referring here to studies. We have set up a number of offices. We have set up an office in the Argonne National Laboratory which is called the Office of Industrial Cooperation, and an office in the Oak Ridge National Laboratory, also called the Office of Industrial Cooperation.

Then, also the Oak Ridge office is making a study of the possibilities of spinoff as they might apply to industry.[35]

The budget request for fiscal year 1967 stated:

Technological Spinoff: Fiscal year 1965, $35,429; fiscal year 1966, $100,000; fiscal year 1967, $150,000: The objective of this activity is to insure the maximum application of results from AEC research and development to non-nuclear industrial use. This activity is implemented largely through the Offices of Industrial Cooperation at Argonne and Oak Ridge which provide industry with information on processes, materials, equipment, techniques, etc., developed in the AEC program. Funds requested for fiscal year 1967 will be used to support the two Offices of Industrial Cooperation and to continue the study of technology transfer mechanisms. Program activities will be coordinated with the Small Business Administration and U.S. Department of Commerce efforts to transfer results of government-funded research and development to private industry.[36]

Cooperation with the NASA program has now extended to the joint issuance of technical publications (see p. 130).

E. Department of Commerce Appropriations

The subcommittees of both the Senate and the House which deal with the Department of Commerce have heard testimony concerning a number of technology transfer related programs.

The civilian industrial technology program was conceived in 1962 with the objective of stimulating research in lagging industries such as textiles, machine tools, and building. Grants and contracts were to be given to manufacturing companies. Although the program never became fully defined, opposition developed on the basis that the Federal funds would be used to expand technology in private industrial sectors. It was alleged that such R. & D. would interfere with the free market competition.

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[35] U.S. Congress. Joint Committee on Atomic Energy. Hearings: AEC Authorizing Legislation, fiscal year 1966. 89th Cong., 1st sess. Pt. 1: p. 36, p. 652.

[36] U.S. Congress. Joint Committee on Atomic Energy. Hearings: AEC Authorizing Legislation, fiscal year 1967. 89th Cong., 2d sess. Pt. 3: p. 1513—Technological Spinoff OIC.

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The Department request stated:

Program development and administration—In cooperation with other interested agencies, studies will be undertaken in order to determine actions which might be taken in order to remove deterrents to desirable innovation, to investigate adaptation to civilian industry of methodology and technology developed in advanced space and defense activities; and to identify changes in Government procurement methods which might stimulate technological improvement. Independent studies of the effectiveness of pilot projects also will be supported in order to establish a sound basis for future program development.[37]

In any event the only appropriations made were for $1,625,000 in 1963 and the main accomplishment of the program was the establishment of an information center for the textile industry. The CIT concept included a variety of technology transfer ideas which have survived in the Office of State Technical Services. But the rejection by Congress of any forthright attempt to use Federal funds for industrial R. & D. was quite forceful.

In October of 1965, after the passage of the State Technical Services Act, the House Appropriations Subcommittee held hearings on a supplemental request for funds. The act authorized $10 million for fiscal year 1966, $20 million for fiscal year 1967, and $30 million for fiscal year 1968, but only $7 million was requested.

Mr. ROONEY. This sounds to me like your so-called civil industrial technology program.

Mr. HOLLOMON. Civilian industrial technology.

Mr. ROONEY. That was completely denied by the Congress. You are now back for the same thing?

Mr. HOLLOMON. No, sir.

Mr. ROONEY. What is the difference between the two?

Mr. HOLLOMON. For the civilian industrial technology program, in the first instance, we came to you for appropriations and not initially through legislation. It was largely a program of research which would be sponsored by the Federal Government. This is not a program of research. This program contemplates decentralized State activities which are matched, and in which the initiative is taken by the States. There was no such activity proposed in the original civilian industrial technology program.[38]

An amount of $3.5 million was finally appropriated for fiscal year 1966 despite an appeal to the Senate subcommittee for restoration of the full amount.[39]

For fiscal year 1967, $8 million was requested. The House Appropriations Subcommittee became concerned as to whether the Department of Commerce had solicited support from the Association of State Universities and Land Grant Colleges for the State Technical Services Act. The preliminary planning work was explained by Dr. A. V. Astin, Director of the Bureau of Standards:

Dr. ASTIN, Sir, we were exploring under this project ways to develop and disseminate technical information more effectively. This was the whole purpose of that operation. That is, we have been of the opinion for a number of years that the proper utilization of technical information by industrial groups in this country requires an appreciation of local or regional problems and dissemination at a local or regional level.

In connection with this there was conducted here about 2 years ago a large conference involving the technical people of most of the State governments, and one of the conclusions of the conference was that it would be desirable to provide staff services for additional conferences and for regional conferences,

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[37] Hearings before the Subcommittee of the House Committee of Interstate and Foreign Commerce, for fiscal year 1964, pp. 747–795.

[38] U.S. Congress. House. Hearings before the Subcommittees of the Committee on Appropriations. Supplemental appropriation bill, 1966. 89th Cong., 1st sess. Pt. 3, pp. 436–451.

[39] U.S. Congress. Senate. Hearings before Subcommittees of the Committee on Appropriations. Supplemental appropriation bill, 1966. 89th Cong., first sess., pp. 789–803.

and that was the primary reason for the setting up of this office which was operated by Mr. Bandy.

One of the other authorities, Mr. Chairman, is the authority of the Secretary of Commerce to stimulate the commerce and industry of the United States. When the Bureau was reorganized 2 years ago the Secretary at that time delegated to the National Bureau of Standards part of his responsibility to serve as the focal point within the Department of Commerce for the application of science and technology to the Nation's industries, so this whole operation as essentially a probing of how better to disseminate information and what kinds of information were the most important when we looked at matters on a regional basis.[40]

Despite some reservations about the operation of the program, 45 of the 50 States were prepared for matching fund grants to begin the analysis of business needs for technology dissemination. The House subcommittee allowed $5 million and the Senate restored an additional $0.5 million for a total fiscal year 1967 appropriation of $5.5 million. Thus out of an authorized $30 million for the first 2 years of operation, only $9 million was appropriated.[41] The budget request for the fiscal year 1968 is $11 million.

F. A Commission on Science and Technology

The Committee on Government Operations of the U.S. Senate has reported virtually identical bills in the 87th, 88th, and 89th Congresses for the establishment of a Commission on Science and Technology. Although the main thrust of the study envisioned would be the feasibility of a Cabinet-level Department of Science, technology transfer is a specific consideration. Section 1(d) of S. 1136 (89th Cong.) states the interest of the Congress in—

insuring the maximum utilization of all available scientific know-how and information by coordinating the research and development programs of the Federal departments and agencies with those of American business and industry and with nonprofit organizations, including universities and other educational or technological institutions.[42]

None of the bills was passed.

G. The Clearinghouse for Federal Scientific and Technical Information

Although routinely funded as a part of the Department of Commerce appropriations, the Clearinghouse was a subject of interest to the Senate Government Operations Committee in its assessment of Government science. A letter from the Bureau of Standards to the chairman on January 28, 1965, reviews the program:

Knowing the longstanding interest of the Committee on Government Operations in the effective provision of Government-generated technical information to industry and the public, I would like to review for you briefly the operations and objectives of the Clearinghouse for Federal Scientific and Technical Information.

The Clearinghouse was established in the Department of Commerce in February 1964, following its endorsement by the Federal Council for Science and Technology and by the Office of the President. At that time, the Commerce Office of Technical Services (OTS) was transferred to the National Bureau of Standards where it was placed under the Institute of Applied Technology. Building upon the existing information services of OTS, the Clearinghouse has undertaken an ex-

[40] U.S. Congress. House. Hearings before a Subcommittee on Appropriations. 89th Cong., second sess., pp. 652, 716–764.

[41] U.S. Congress. Senate. Hearings before the Subcommittee of the Committee on Appropriations on H.R. 18119, 89th Cong., 2d sess., pp. 334, 443–455.

[42] U.S. Congress. Senate. Committee on Government Operations. Report on S. 1136. Committee print. 89th Cong., 1st sess. 1965. P. 8.

panded role as the national center for the dissemination of Government-generated information in the physical sciences, engineering, and related technology. In brief, the Clearinghouse has been established as the single point of contact in the executive branch for supplying the industrial and technical community with unclassified information about Government-sponsored research and development in defense, space, atomic energy, and other national programs. It thus makes readily available, at low cost, research information which may aid in the development of a new product, solve a processing problem, or increase productivity through technical improvement.

In addition to supplying documents, the Clearinghouse functions also include provision of information on Government research in progress, referral to sources of specialized technical expertise in the Government, and the development of effective means of conveying this information to the various sections of the country, adapting it to the needs and interests of local industrial and technical groups.[43]

The Clearinghouse currently receives 22,000 documents each year.

H. Scientific and Technical Manpower

The Subcommittee on Employment and Manpower of the Senate Committee on Labor and Public Welfare held hearings in 1965 on "The Impact of Federal Research and Development Policies Upon Scientific and Technical Manpower." [44]

In the report issued subsequently, technology transfer was seen to be a part of this broad issue. The importance of being a Federal contractor in order to have access to R. & D. results was discussed:

In addition, favored firms that perform Federal research and development have the built-in advantage of knowing the results of this work and are able to use this information to advantage in subsequent skirmishes for contracts. Eugene Foley, of the SBA, has suggested that research and development performers should submit reports on potential commercial applications of what has been researched or developed. Such reports do not seem feasible, but the suggestion indicates the extent to which other firms—especially small firms—can be handicapped solely by a lack of appropriate information.[45]

The secondary effects of research and development awards were the major ones with which the subcommittee was concerned. It is difficult to assess the direct effects of a research and development award; and the secondary effects constitute an even more difficult and complex process to assess, for they involve new industry, better schools, and community attitudes receptive to the pressures for growth and development.[46]

Another possible important industrial effect of research and development funds, however, is the so-called spinoff. While engaged in research, and also in development, a university or company scientist may uncover a new process, a new material, or simply a new idea that has worthwhile industrial application. A spin-off company is born; a firm may be attracted or established; and a major new product or industry may result. Again, the cycle of Government contracts, scientists, and businesses can be set in motion and area growth can be stimulated.[47]

I. The House Select Committee on Government Research

In 1963 the House of Representatives established a Select Committee on Government Research to undertake a broad review of Federal service. The importance of technology transfer was discussed in the summary of the hearings.[48]

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[43] *Ibid.*, pp. 60–61.
[44] U.S. Congress. Senate. Committee on Labor and Public Welfare. The Impact of Federal Research and Development Policies Upon Scientific and Technical Manpower. Report of the Subcommittee on Employment, Manpower, and Poverty. 89th Cong., 2d sess. December 1966. (Committee print.)
[45] *Ibid.*, p. 51.
[46] *Ibid*, p. 38.
[47] *Ibid*, p. 39
[48] Summary of hearings before the Select Committee on Government Research of the House of Representatives, 88th Congress, 1st and 2d sessions, pt. 3, pp. 1233–4.

"*Effectiveness of converting R. & D. into practical products* (*Vickers*)

"Research and development is viewed as a pyramid of four parts. At the top is basic research; the greater the incentive for the researcher to put his findings to use, the closer he approaches the next segment of the pyramid. The next segment is applied research, which carries forward the application of scientific principles toward ulimate production of useful results. The third segment is development, and the fourth section or base of the pyramid is production.

"This, in our view, must be the paramount and ultimate goal of the whole research and development process. It is through the production and distribution of the fruits of research and engineering that each citizen—who in fact pays for the whole effort—receives the benefits for which he pays.

"If the committee concurs with this premise, then the emphasis in its appraisal of Government's role in research and development should be upon how effective is the process of coverting research and development into practical end products serving the Nation. Inasmuch as only industry is or should be exclusively involved in the functions of production, sale, and distribution, it is apparent that the interfaces between the four segments of the pyramid and thus also of the Government-industry relationship become of utmost importance (pp. 1064–1065).

"*Finding useful byproducts of R. & D.* (*Halaby*)

"More attention should be given to getting double duty out of development dollars by gleaning new products and byproducts of research. Just as in industry, in the various agencies there should be someone constantly watching for things that can be picked out of the research and development programs and made usable for civil applications (p. 131).

"*Relationship between the military and industry in use of results of defense R. & D.* (*Teller*)

"(A member of the committee questioned the witness concerning (1) the charge that too much time and attention are devoted to military R. & D. at the expense of the civilian economy; and in particular to (2) the charge that the military, under the guise of security requirements, do not release results of R. & D. for civilian use.)

"I am under the impression that there has been a conscientious effort and an effort that has paid off to make available the results of our military research to our economy. One example is the development of our planes. * * *

"I do not deny that there may have been cases where better, earlier availability would have been of help. But in general I think this charge is based on an exaggeration, I mean the charge that military developments are not available to the civilians. This is an exaggeration.

"In one respect, however, the charge may be valid, but this is not due to action of the armed forces.

"* * * We have laws, very restrictive laws, concerning security. In many areas you are not allowed to communicate to the industry unless it is first clearly and completely proven that publication cannot possibly hurt our country. Such proof is immensely hard to get.

* * * * * * *

"I believe that at any rate the burden of proof should be on the other side. Things should be open, unless proved to be dangerous. * * * The willingness for cooperation is there. The practice of cooperation is there. But some of our laws make the cooperation unnecessarily difficult. (pp. 942–944, 951).

"*Usefulness of military and space R. & D. in the civilian economy* (*Foley*)

"Most Government R. & D. work is directed toward national defense. For the most part, the implications (the spillover) of military technology for civilian uses are largely unexplored. The Small Business Administration is conducting such explorations, and is working with the National Science Foundation, the National Aeronautics and Space Administration, and the Department of Commerce to supply small business concerns with usable information derived from Government-funded R. & D. The SBA is conducting several services for transmitting such information to small business.

"It must be recognized that the knowledge gained from Government expenditures in space and military research and development can, in many cases, be transferred directly into industrial application. This information contains the potential for creating new industrial techniques, materials, products and processes. If assimilated properly, it can exert a profound influence on our civilian technology. The Federal Government, therefore, has an obligation to develop a workable system of utilizing this enormous reservoir of scientific information so that its benefits can be transmitted to businessmen both large and small in order to provide the ingredients necessary for an accelerated growth in our civilian economy. * * * (pp. 741–742)."

The report of the select committee contains a description of current Federal transfer programs.[49]

Among the findings of the report were:

18. Research and development can significantly contribute to growth of the general economy as well as of a given industry. Our current national rate of economic growth is less than that of several other nations. The question arises whether our research and development effort can be better marshaled to help accelerate our economic growth rate.

19. A traditional concept has been that spillover, or product-process spinoff, from our space and military research and development programs (which dominate the total national research and development effort) spurs development and utilization of new products and systems and ultimately, generally growth. This concept can be challenged, for the record in this regard is far from conclusive. While few would be willing to eliminate all programs designed to transfer to the general civilian economy the results of our Federal research and development activities, we must continue trying to arrive at a better formula for converting the fruits of our research efforts into economic sinews for the Nation.[50]

J. The National Commission on Technology, Automation, and Economic Progress

At executive request, the Congress passed Public Law 88–444 creating the National Commission on Technology, Automation, and Economic Progress. The Commission was charged, in part:

(d) To assess the most effective means for channeling new technologies into promising directions, including civilian industries where accelerated technological advancements will yield general benefits, and assess the proper relationship between governmental and private investment in the application of new technologies to large-scale human and community needs; [51]

The Commission generated a number of thorough studies for its deliberations. The original motivation was the need for creative public policies in marshaling the techniques of science for human welfare without unwanted consequences of unemployment, economic dislocations, or other social upheavals. One of the most important studies was concerned with technology transfer.[52]

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[49] Study No. VI, Impact of Federal research and development programs. Report of the Select Committee on Government Research of the House of Representatives, 88th Cong., second sess., Dec. 28, 1964, p. 131.

[50] *Ibid.*, p. 144.

[51] Op. cit, ref. *a*, vol. I.

[52] Lesher, Richard C., and Howick, George J., "Background, Guidelines and Recommendations for Use in Assessing Effective Means of Channeling New Technologies in Promising Directions." *Ibid.*, vol. V.

The section in the final report dealing with this subject is reproduced in full because of its relevance to the present inquiry.[52(a)]

THE GENERATION AND TRANSFER OF TECHNOLOGY

The evidence is overwhelming that technology stimulates the rate and volume of economic growth, and that the infusion of new technology can speed the rate of economic growth. It is evident that increases in GNP are related to expenditures for research and development. R. & D. expenditures are still rising rapidly. In 1965, a total of about $21 billion will be devoted to R. & D., about $15 billion of which will be spent or supplied by the Federal Government. The way in which R. & D. is spent is important both for the pace of technological advance and for the determination of the areas where technology will—and can—be applied.

Four questions of policy arise in relation to R. & D. expenditures and the uses of technology for economic growth and social needs:

1. Is there some "optimal limit" to the amount of R. & D. expenditures, based on our ability to develop enough well-trained research manpower, to use these expenditures well?

2. Are there significant "imbalances" in the present pattern of R. & D. expenditures, particularly by the Federal Government?

3. What can be done to stimulate the greater use of R. & D. by lagging industries?

4. What kind of Federal policy is necessary for the dissemination of technological knowledge to potential users—problems ranging from the organization of comprehensive information retrieval systems to the direct assistance of communities, small business, and other industries in gaining access to publicly avalable technological knowledge?

A determination of an optimum research and development expenditure is a most difficult question. Private industry has a basic market test of its ability to devote some portion of its capital investment for research and development; at some point R. & D. has to "pay off" or the company cuts its expenditure in a specific area. What the limit of Federal expenditures should be, however, is difficult because we have no test of the potentialities of R. & D. In some areas (e.g., defense or basic research) one may want to encourage experimentation, even where there is no immediate possibility of payoff (either in profitability or in new knowledge) because of the intrinsic worthwhileness of such experiments. It has been suggested that precise figures should be gathered which show the annual employment of scientific manpower and dollars in relation to the putative national goals they serve. Such a report might provide the framework for a more detailed consideration of the kinds of Government expenditures on R. & D.

The question of imbalances in existing spending is one which involves political judgments. Over half the Federal budget is devoted to defense and it is, therefore, not surprising that the largest part of Federal R. & D. funds are in support of defense objectives. But we also feel that other areas—principally housing, transportation, and urban development—have been neglected in federally supported R. & D. efforts, and considerably more has to be done in these fields.

It has been argued that some industries have lagged technologically because of the disproportions in R. & D. spending or the failure to apply in other areas technologies developed for one area. The concentration of research and development in a few industries is not, per se, evidence of misallocation. Technological opportunities are greater in some fields than in others, and uneven distribution of R. & D. does not itself indicate inefficient resource allocation within industry. Nor is there evidence that increased R. & D. would necessarily stimulate change in all industries.

The relevant question is whether it is possible to help potential users who are unable for a while to help themselves. Government support of research and development in agriculture and aviation has reaped rich economic rewards. In areas where market criteria cannot generate sufficient incentives for adequate research and development—such as weather forcasting, public health, education—the Federal Government has a recognized responsibility. And where R. & D. benefits are insufficiently realized through private capabilities, it is the task of public policy to provide incentives. The responsibility is not necessarily that of doing research or even financing it, but of providing incentives for getting it done.

[52(a)] *Ibid.*, p. 103.
[53-57] These references will be found in the notes to table 1, p. 32.

The transfer of technologies developed in Federal laboratories and agencies for industrial and consumer use requires a more forthright and unified Government policy than exists at present. Technology transfer—using new technology for purposes other than the specific ones for which it was developed—is not given much attention in many Government agencies. Locating the technology and identifying new and different uses require the assignment of competent persons within the agencies for such tasks and the cooperation of the many different scientific and technical missions. Until this task is given a higher priority, there will be gaps in the collection of important technological information.

The other side of the coin is the reporting and dissemination of such information to potential users. There, too, a national policy is necessary. The Government can engage in a variety of activities, from the simple publication of documents (placing the burden of discovery on the potential user) to such more active roles as centralizing all bibliographical citations in an information retrieval system, the creation of technical consulting services (available, for example, to small businesses), or the use of governmental facilities by nonprofit institutions for the adaptation of new technologies for commercial purposes.

Given the range of possible activities, we cannot within our limited purview define the exact limits of governmental involvement. Certainly, it would seem that the Federal Government has a legitimate role developing weather satellites and medical research equipment. But we cannot say that it is an obligation of Government to assist all claimants or engage in partnership with profit or nonprofit organizations to develop all new technologies or devices originated by Government for civilian use. These are questions to be decided on the broader base of national goals. As a minimum we do feel that the Government has a responsibility for making available for nongovernmental utilization the result of Government-performed research and other research that was substantially funded by the Government. The issue, in the future, will be a vexing one, and more detailed study is needed.

K. Summary

The recent attention to technology transfer has come as a peripheral issue to a variety of programs, bills, and congressional concerns. The potential in the large and growing body of knowledge produced under Federal funding is viewed in relationship to needs for regional development, revitalizing certain industries, strengthening the Nation's international trade position and assuring economic health. Further, there is a certain appeal to "Yankee" thrift in obtaining the maximum benefits from a resource that has been obtained at considerable cost.

However, there is some caution in defining the degree to which the Government can become involved in what is essentially the private business problem of growth, diversification, and survival in the competitive market. None of the trial programs or experimental agencies has had a dramatic effect on the natural process of technology diffusion. And the present efforts are individually concerned with different portions of the overall process. The Congress has recognized the transfer of certain large packages of technology from Government R. & D. These include the civilian nuclear power reactors, jet aircraft, and computers. Furthermore, the direct Federal funding of R. & D. in the private interest has been approved continually in medicine, agriculture, and natural resources development.

The record shows a consistent call for policy definition in the gray area of technology from military space nuclear projects. Witnesses from the business and scientific communities, as well as legislators and agency administrators are agreed on this point. Therefore, the present study is a further response with the hope of elucidating technology transfer and formulating a guiding policy for the future.

V. SCIENTIFIC RESEARCH AND DEVELOPMENT IN THE UNITED STATES

A. Historical Funding and Performance Statistics

In order to understand the possibilities for technology transfer, an analysis of the funding and performance of R. & D. is necessary. Table 1 presents a summary of these activities for the period 1957–67. Unfortunately some data are only available for fiscal year (July to June) periods, but because year-to-year changes are in a generally increasing direction and not large relative to previous years, the comparisons are believed valid. To provide an accumulative value, a summation of the 10-year period 1957–66 has been made.

TABLE 1.—*Summary of R. & D. activities in the United States, 1957–67*

[Dollar amounts in billions]

	Item	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1957–66 total	
1	Total R. & D. performed in the United States, calendar years	$9.9	$10.9	$12.5	$13.7	$14.6	$15.7	$17.4	$19.1	$20.5	$23.2	$24.0	$157.5	1
2	Total Federal obligations for R. & D., fiscal years	3.9	4.6	6.7	7.5	9.1	10.3	12.5	14.2	14.6	[1] 15.9	[1] 15.9	99.3	2
3	Federal R. & D. performed intramurally, fiscal years	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.8	3.1	[1] 3.3	[1] 3.4	21.4	3
4	Federal R. & D. performed by industry, fiscal years	2.2	2.6	4.2	4.8	5.9	6.6	8.3	9.1	9.1	[1] 10.0	[1] 9.7	62.8	4
5	Federal R. & D. performed by others, fiscal years	.5	.6	.8	1.0	1.3	1.6	1.9	2.1	2.4	[1] 2.7	[1] 2.9	14.9	5
6	Total industrially performed R. & D., calendar years	7.7	8.4	9.6	10.5	10.9	11.5	12.6	13.5	14.2	[1] 16.5	[1] 17.1	115.4	6
7	Industrially performed R. & D. funded by Federal Government, calendar years.	4.3	4.8	5.6	6.1	6.2	6.4	7.3	7.7	7.8	[1] 9.5	[1] 8.9	65.7	7
8	Industrially performed R. & D. funded by company, calendar years.	3.4	3.6	4.0	4.4	4.7	5.0	5.4	5.8	6.4	[1] 7.0	[1] 8.2	49.6	8
9	R. & D. obligations, Department of Defense, fiscal years	3.0	3.4	5.1	5.8	6.6	6.7	7.3	7.3	6.8	7.4	7.3	59.4	9
10	R. & D. obligations, Atomic Energy Commission, fiscal years	.5	.6	.7	.8	.8	1.2	1.1	1.2	1.2	1.3	1.3	9.4	10
11	R. & D. obligations, National Aeronautics and Space Agency, fiscal years.	--------	.1	.3	.4	.8	1.4	2.9	4.3	5.0	5.2	4.9	20.4	11
12	3-agency total (lines 9, 10, and 11) fiscal years	3.5	4.1	6.1	7.0	8.2	9.3	11.3	12.8	13.0	13.9	13.5	89.2	12
13	Gross national product, calendar years	441.0	447.0	484.0	504.0	520.0	560.0	591.0	632.0	681.0	740.0	--------	--------	13
14	Percent of total R. & D. performed by industry (lines 6/1)	78.0	77.0	77.0	77.0	75.0	73.0	73.0	71.0	71.0	71.0	73.0	74.0	14
15	Percent of total R. & D. funded by Federal Government (lines 2/1)	39.0	42.5	54.0	55.0	62.0	66.0	72.0	75.0	69.0	68.0	68.0	63.0	15
16	Percent of Federal funded R. & D. performed by industry (lines 4/2).	56.0	57.0	63.0	64.0	65.0	64.0	66.0	64.0	62.0	63.0	61.0	63.0	16
17	Percent of total industrially performed R. & D. funded by Federal Government (lines 7/6).	56.0	57.0	59.0	58.0	57.0	56.0	58.0	57.0	58.0	58.0	52.0	57.0	17
18	Percent of total R. & D. funded by 3 agencies (lines 12/1)	35.0	38.0	49.0	51.0	55.0	59.0	65.0	67.0	61.0	60.0	58.0	56.0	18
19	Total R. & D. as a percentage of GNP (lines 1/13)	2.2	2.4	2.6	2.7	2.8	2.8	3.0	3.0	3.2	3.1	--------	--------	19

[1] Estimated.

NOTES

Line 1: Estimated by adding lines 3, 5, and 6 plus R. & D. performed in universities, research institutes, and private foundations which is supported by their own funds.

Lines 2, 3, 4, and 5: From table C–58, p. 163, "Federal funds for research, development, and other scientific activities," vol. XV, National Science Foundation, Washington, D.C., 1966 (reference 53).

Lines 6, 7, and 8: From table 1, p. 17, "Basic research, applied research and development in industry, 1964, "National Science Foundation, Washington, D.C., 1966 (reference 54) and "Reviews of Data on Science Resources," National Science Foundation 66-33, December 1966 (reference 55). Estimated values for 1966 and 1967 are based on data from an annual survey reported in Industrial Research magazine, January 1966, p. 36, and January 1967, p. 52 (reference 56).

Lines 9, 10, 11, and 12: Derived from table C–54, p. 159, and table C–57, p. 162, "Federal Funds," vol. XV (reference 53).

Line 13: Economic Report of the President, January 1967, p. 213 (reference 57).

Line 1 shows that the total amount of scientific and engineering activity in research and development (that is, exclusive of production engineering, education, routine testing, etc.) has risen from $9.9 billion in 1957 to $24 billion forecast for 1967. Most of this expenditure goes directly to final demand and so can be calculated to account for about 3 percent of the gross national product at the present time (line 19).

Lines 2 and 8 show that starting from about the same level in 1957, the Federal funding has quadrupled whereas private industry funding has doubled. This is an indication of several factors: (1) science and technology have been recognized as increasingly important in serving many national interests; (2) strong science is a responsibility of government; and (3) many large-scale technological projects are beyond the funding capacity of commercial interests. Other factors contribute to the dollar growth but do not necessarily reflect more effort. Inflation, rising salaries and increased use of expensive tools, instruments and special apparatus swell the totals. Funds for R. & D. facilities are not included in these data but the Federal Government has obligated $7.6 billion for this purpose in the 1957–66 period and private investment has probably been comparable.

Line 3 indicates that the Federal laboratories were expanded appreciably (corresponding with the NASA program) but have been stable for the last few years. The long standing policy of the Government has been to do a sufficient amount of R. & D. intramurally to assure competence in monitoring grant and contract work and to identify promising areas of science. Beyond that point, nongovernment institutions are chosen to perform the work. Contract research centers such as the Jet Propulsion Laboratory operated by the California Institute of Technology or Oak Ridge National Laboratory operated by Union Carbide Corp. are counted as university and industry performance respectively.

Line 4 reflects the fact that industry is the major performer of Federal R. & D. This, in a sense, means that the technology developed does not have to be transferred to the private sector because it is already there. However, performance by profitmaking firms may not mean any closer tie to civilian products, processes or services than if the work was done in a Government laboratory. Some industrial laboratories segregate commercial and Federal projects to avoid patent and proprietary information problems. The Federal agency guides and controls the project, keeping its own goal uppermost and preventing excursions or extenuations into interesting lines of investigations which are not germane. Promising but nonrelevant findings may be dropped before they are carried far enough to interest a commercial developer. A Government-funded team may be broken up by a canceled or finished program without tying up the loose ends of technology into a communicable package.

Federally funded R. & D. performed by industry has been successful in obtaining results. The low salary scales of civil service have been circumvented. Unwieldy facilities and organizations have not been permanently added to the Government structure. On the other hand, some privately operated organizations have become claimants on continued Government funding, much as would Federal laboratories. But, taken as a whole, the research and development results are not fully integrated into the commercial technological stream.

R. & D. performed by others (line 5) means educational institutions and the contract research centers which they operate, private nonprofit institutions, State and local governments and individuals. This expanding category reflects mainly the Federal support of basic research in the universities. Much of this work does not result in immediately applicable technology. Also the concentration by the institutions of higher learning on Federal research may have made them less interested in, and aware of, industrial development needs. The special effect which Government funding has had on nonprofit independent research institutes is discussed on page 79.

Total industrial performance is shown in line 6, indicating that the private sector R. & D. capability has more than doubled in the past 10 years. Lines 7 and 8 show that the increase has been proportionately the same for both Federal and corporate funding sources. The discrepancies in earlier years between lines 4 and 7 cannot be explained by the National Science Foundation which issues both sets of figures. Federal agencies report their funds which go to industry. An industrial survey reports funds received from government. Minor differences are attributed to accounting practice, the lag between obligations and expenditures and incompleteness of industrial data. The NSF warns:

"The extent of federally financed R. & D. performance in certain industries may be understated because some companies, in reporting their R. & D. figures, fail to account for the portion of company initiated R. & D. projects indirectly financed through overhead payments under Federal contracts." [57a]

None of these reasons would account for the industry total's being *greater* than the agency figure as is the case for 1957–61.

The very large impact of just three agency programs is shown in lines 9, 10, 11, and 12. The Department of Defense, the Atomic Energy Commission, and the National Aeronautics and Space Administration, in their national security/prestige programs represent over half the total U.S. R. & D. activity in each year since 1960 (line 18).

The Department of Defense alone has funded one-third of the total for the past 10 years. These R. & D. programs were seen to be vital to the national goals and strategies involved, and so have generated their own funding justification, facilities, and management resources in the military/space industry. In this sense the R. & D. results are in excess to those which would have come normally from commercial and other Government projects. It cannot be said that the same amount of R. & D. would be performed (but for other purposes) if these three agencies did not exist. There is no R. & D. "pie" to be divided up. Rather, R. & D. is funded, both publicly and privately, in the amount judged necessary to support missions and objectives. The only limiting resource is trained manpower; and the redeployment of scientists and engineers is a major concern as large technology programs wax and wane, or as emphasis shifts among fields and disciplines.

[57a] *Op. cit.* ref. 54, p. ix.

B. Distortions in U.S. Technology

1. Sponsorship

Research and development has an uneven character which is reflected in the kind of technology in the reservoir available for transfer efforts. To document and describe these distortions, a 10-year total is examined in table 1. From 1957 to 1966, $158 billion worth of scientific and engineering activity was performed. The Federal Government has provided 63 percent (line 15) or $99 billion of the money, while 74 percent (line 14) or $115 billion was performed in the profit sector. Of the $99 billion, $63 billion or 63 percent (line 16) went to industry.

The R. & D. resources of industry were devoted to Federal programs to the extent of 57 percent (line 17), or $66.5 billion out of $115 billion. The amount of R. & D. performed completely external to commercial laboratories was $36.3 billion in this decade. For technology transfer considerations, the results of this work must be packaged and transported across Government-industry lines if they are to be useful in civilian applications. The entire $99 billion Federal portion may be considered to have been performed primarily for Government agency purposes even though 63 percent of the work was in industrial laboratories. Thus, some special effort is indicated to obtain the fullest use of about two-thirds of all the R. & D. work in the United States in the past 10 years. This is the rationale for seeking a clear policy for technology transfer.

2. Manpower

A measure of the distribution of scientific manpower resources may be gained from table 2. These data represent returns from a survey of about 415,000 individual scientists in the United States, believed to include 90 percent of the Nations natural science doctorates. It should be noted that engineers are not covered by this survey. Research and development work accounts for about one-half of all scientists and about one-half of this portion is employed in industry (47,463 out of 223,854). Basic research is concentrated in universities while the majority of applied research employment is in industry. All types of governmental activity account for 18.2 percent of R. & D. scientists.

Of significance to technology transfer is the fact that about half the R. & D. scientists are in some other type of employment than industry. This infers that good communications are essential if industrial workers are to have wide access to new scientific knowledge.

This scientific manpower distribution does not correlate too well with the dollar distribution in table 1. Whereas the percentage of R. & D. scientists in industry is 46.5, the percentage of dollar performance is 74. (See p. 32.) This is probably due to the heavy engineering effort in industry which is not reflected in this table. It is estimated that 358,900 equivalent full-time scientists and engineers were employed in industry to do research and development as of January 1966.[57b] The total number of scientists and engineers in the United States is estimated for 1966 at 1.5 million (see table 3). The

[57b] Op. cit., reference 55, p. 12.

total R. & D. manpower figure for all performers is estimated at about 500,000.

TABLE 2.—*Number of scientists, by work activity and type of employer, 1964* [1]

Work activity	Total	Type of employer: Educational institutions	Federal Government	Other government	Military	Nonprofit organization	Industry and business	Other
All activities	223,854	77,727	23,405	7,472	5,522	8,722	84,421	16,595
Research and development	77,699	26,392	10,242	2,006	999	4,344	32,741	975
Basic research	35,781	19,894	5,002	779	531	2,334	6,863	378
Applied research	30,280	6,047	4,535	1,148	405	1,739	15,924	482
Research management	24,568	2,793	3,846	908	631	1,257	14,722	411
Total R. & D.	102,267	29,185	14,088	2,914	1,630	5,601	47,473	1,386
Percent of total R. & D.	100	28.4	13.8	2.8	1.6	5.5	46.5	1.4

[1] Adapted from "American Science Manpower, 1964," National Science Foundation, NSF 66-29, 1966, table 11, 0. 60.

TABLE 3.—SCIENTISTS (INCLUDING SOCIAL SCIENTISTS) AND ENGINEERS, BY INSTITUTION IN WHICH EMPLOYED, 1965

Industry	1,010,000
Government (Federal, State, and local)	235,000
Colleges and universities	175,000
Nonprofits	16,000
Total	1,436,000

Source: Information supplied to the Legislative Reference Service by Mr. Norman Selzer, Office of Economic and Manpower Studies, National Science Foundation, February, 1967.

3. INDUSTRIAL SECTORS

Another distortion is presented in table 4 where the largest industry sectors performing R. & D. are listed. These five industries are seen to account for 83 percent of all industrially performed R. & D. as estimated for 1967. The same five account for 92 percent of Federal funds to industry and 73 percent of all company funds. As might be expected, the aircraft and missiles (space) category together with electrical equipment and communications dominate the entire picture, representing 84 percent of all Federal funds to industry. The impact of these expenditures is noted in the frequent reference to jet air transports and computers as prime examples of technology transfer to civilian application.

The concentration of R. & D. in these sectors is out of proportion to their importance to the economy in sales and employment. Federal money provides the bulk of aerospace and electronics work, while private funds are the mainstay of research and development in chemicals, transportation and machinery. Perhaps the distortion is shown more clearly by the industrial categories which are not represented in the table. For 1965 (the last year in which information is available) the National Science Foundation lists the following industries as each performing only about 1 percent of the total private sector R. & D.: food and kindred products; textiles and apparel, lumber, wood products, and furniture; paper and allied products, rubber products; fabricated metal products and stone, clay, and glass products,[57c] yet these industries account for a substantial portion of the gross national product.

In another study, it is pointed out that "the 20 manufacturing companies with the largest R. & D. programs accounted for 58 percent of the R. & D. funds but only 18 percent of the net sales and 21 percent of the employment of all manufacturing companies that reported R. & D. performance." [57d] These same 20 companies accounted for 71 percent of Federal funds but only 38 percent of company funds for industrially performed R. & D.

TABLE 4.—*R. & D. performed, by industry classification, 1967—Estimated expenditures* [1]

[Dollar amounts in billions]

Industry	Company funds	Federal funds	Total	Federal funding as percent of total
All	$8.2	$8.9	$17.1	52
Aircraft and missiles	.7	5.0	5.7	88
Electrical equipment and communications	1.35	2.45	3.8	65
Total of 2 industries	2.05	7.45	9.5	78
2-industry total as percent of all industries	25	84	56	
Chemicals and allied products	$1.6	$0.3	$1.9	16
Motor vehicles and other transportation equipment	1.25	.15	1.4	11
Machinery	1.1	.3	1.4	21
Total of 5 industries	6.0	8.2	14.2	58
5-industry total as percent of all industry	73	92	83	

[1] Adapted from data in Industrial Research, January 1967, p. 53 (reference 56).

So it can be seen that the appearance of new technology is not uniform throughout the economy. It is more readily available in a few large companies in certain industries. Many other firms, large and small, may look at this concentration of research results (provided largely by public funds) as a desirable source of technology if a transfer process can be provided. However, industries not heavily involved in R & D are usually those where technology has not yet been judged to be a critical ingredient for growth and survival. Firms which do not presently support some scientific and engineering activity of their own are not likely to be alert seekers of transferred technology.

Other breakdowns of the gross total of R. & D. dollars are useful to show the type and character of the work. These divisions do not imply that there is anything wrong with the allocation of scientific resources but they do indicate the relative volume of different kinds of technology available for transfer. Some research fields which might seem most relevant to civilian commerce or new public problems have not been heavily supported by Federal funding.

In the 10-year 1957–66 period, $10 billion of Federal funding has gone to basic research, $20 billion to applied research and $70 billion to development.[58]

[57c] Op. cit., reference 55, p. 5.
[57d] Op. cit., reference 54, p. 4.
[58] Op. cit., ref. 53 p. 159.

The basic research work for the most part does not take ideas far enough along to provide technology for transfer, although research results themselves are highly transferable among scientific fields for further development. The $70 billion produces a great deal of technology in the course of development, invention, innovation and preproduction engineering. There is no available breakdown of this sum as to field of science.

4. FIELD OF SCIENCE OR ENGINEERING

The $20 billion for applied research in the last decade is a primary source of transferable technology and some view of its distribution can be gained from the following percentage composition as estimated from data for fiscal year 1967.[59] In decreasing order of support, the fields are: Medical sciences, 19.6 percent; aeronautical engineering, 8.7 percent; astronautical engineering, 8.3 percent; electrical engineering, 8.3 percent; solid earth sciences, 6.9 percent; physics, 5.9 percent; social sciences, 4 percent; chemistry, 4 percent; atmospheric sciences, 4 percent; chemical engineering, 3 percent; mechanical engineering, 3 percent; metallurgy and materials, 3 percent; biological sciences, 2.3 percent; psychological sciences, 2.1 percent; mathematical sciences, 2 percent; agricultural sciences, 1.8 percent; oceanography, 0.7 percent; civil engineering, 0.7 percent; and astronomy, 0.4 percent.

The significance of this composition for technology transfer is that some lagging civilian industries (e.g., textiles or housing) are unlikely to find large blocks of federally sponsored research directly related to their operations. This does not mean that some novel device or technique in astronautical engineering would not be applicable. But the overlap of fields of science and engineering may not be substantial. So, horizontal transfer with subsequent further development will prove to be more likely than the straightforward acquisition of technology in the industrial field which needs only vertical transfer into salable products.

5. GEOGRAPHICAL DISTRIBUTION

The geographical distribution of R. & D. performance also poses problems for technology transfer. The word "geographical" is not the correct adjective to describe the nonuniformity of R. & D. within the United States, but its inferred meaning is well known. Equitable distribution does not refer to an equal number of scientists per square mile; rather, the concept is that R. & D. are important to economic vitality of a region, both as prerequisities for industrial growth and as support for continued progress. For a variety of reasons, agglomeration of scientific laboratories occurs. These concentrations match fairly well the industrial centers of the United States, particularly the Los Angeles-San Francisco, Milwaukee–Pittsburgh, and Boston-Washington bands.

[59] Op. cit., reference 53 p. 123.

VI. TECHNOLOGY TRANSFER AS AN INTERNATIONAL PROBLEM

A. Foreign Country Programs

The transfer of technology from one economic area to another is a problem common to the industrially advanced countries of the world. Both democratic and totalitarian systems are acutely aware of the need to speed the flow of technology within the state, and of the advantage in institutionalizing innovative mechanisms between research programs and industrial and commercial sectors. Underlying this concern is a recognition of the increasingly important impact of science and technology on economic development. Government economic plans are being broadened in scope to take into account national strategies for the utilization of scientific and technological resources. Yet, economic plans translate into operating programs that vary somewhat from country to country. Differences in the public/private relationship and in the technological complexion of a particular nation provide the motivations for the variety of approaches designed to facilitate technology transfer.

1. U.S.S.R.

The Soviet Union has experienced difficulty in spreading technological know-how throughout their industrial and commercial complex. An organizational gap has existed between basic and applied research—the former is under the aegis of the Academy of Sciences and the latter is largely located within the industrial ministries. The Soviets have had to contend with a semiautonomous growth of many of their industries, which has prompted the pendulum of change to swing from centralization to decentralization in the search for more effective coordination across ministry lines.

Recently top Russian science administrators and party officials showed great concern for the technology transfer problem. At the 23d Party Congress in 1966 new policies and programs were offered. More scientists will be encouraged to work in applied research and development facilities. Information networks are planned under the direction of the All Union Institute of Scientific and Technical Information (VINITI). The network, as conceived, will connect territorial and functional information centers for the purpose of preventing duplication of research activities and facilitating management control. Included will be all unclassified results from the space and defense programs.

Three other nations—Great Britain, The Netherlands, and France—offer illustrative examples of how other governments are proceeding to solve this problem. Meaningful comparisons can be made between these three countries and the United States because of the similar political/economic structures and the heavy commitment of each government to the support of research and development.

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2. THE NETHERLANDS

The Netherlands has created a unique scientific institution. The Central Organization for Applied Scientific Research (TNO), established in 1930, is a science service corporation independent of governmental control. It is the axis on which turns the Dutch system of government/industry partnership in the application of science. Through the efforts of research institutes, service departments (Mathematics and Statistics Department, Patent Department) and numerous committees, TNO attempts to respond quickly to the research needs of industry.

A board of directors composed of experts in the natural sciences and economic affairs governs the Central Organization. Four specialized research organizations—Organization for Industrial Research (1934), Organization for Nutrition and Food Research (1940), National Defense Research Organization (1946), Organization for Health Research (1949)—are constituted under the Central Organization, which coordinates their activities.

TNO receives support from the government and private industry. The Ministry of Finance grants to it an annual subsidy (67,000,000 Dutch gilders in 1966). The funds are allocated according to the needs of the specialized organizations and provide for the acquisition of equipment, facilities and personnel. All decisions are made by the governing board in conjunction with the directors of the four research bodies. Government influence, however slight, is to be noted in that each Ministry with a direct concern in the activities of TNO sends a delegate to the board.

Industry supports TNO when a contract is made with one of the research institutes or service departments. A corporation that decides it needs to have research done on a problem is free to negotiate with TNO. Once the agreement is made, TNO takes steps to protect the proprietary rights of their temporary client. Medium and large size industries account for almost all of the research. "For small industries (below 100 employees) . . . the hard fact is that they do not know—even still now do not know—how to fit science in their shops." [59a]

The result of this firmly established institution is a triangle of interaction between government, enterprise and science.

3. UNITED KINGDOM

a. The Ministry of Technology

When the Labor Government stepped into power at the end of 1964, it brought about a drastic change in the governmental organization for science and technology. A new Ministry of Technology was created which would command ultimately the entire research and development functions of the British Government with the exception of Government-supported research at universities. (The Ministry of Science and Education would retain that responsibility.) The reorganization was predicated on the assumption that a "modern industrial nation requires a concentration of power in an organization capable of initiating change." [60]

[59a] U.S. Congress. House Subcommittee on Science Research and Development of the Committee on Science and Astronautics, Eighth Meeting of the Panel on Science and Technology, statement by H. W. Julius, "Government-Industry Partnership in Scientific Applications," 90th Congress, 1st Sess, January 24, 1967, Washington, D.C., U.S. Govt. Print. Off., 1967. 11 p.

[60] "The Short History of the Ministry of Technology," Nature, July 9, 1966, p. 115.

The anticipated consolidation of research and development functions was not consummated until late 1966 when it was announced that the Ministry would be responsible for all defense research and development. The action erased much of the uncertainty about fulfilling the original mandate.

The innovative approach that the Ministry would take has been summarized by Prime Minister Wilson. The three major functions would be to:

1. Generate general technological advance and deal effectively with factors which promote or impede such advances.
   —forge closer links between industry, government, and universities in ideas, people, and research.
   —increase flow of talent into technological disciplines.
   —disseminate information on technological development.
   —analyze impact of incentives on promoting innovation in industry.
2. Improve the Government role of stimulator by enhancing "fall out" of in-house research. Four areas were mentioned:
   —Atomic Energy Authority.
   —National Research Development Corporation.
   —relevant Government research stations.
   —contacts with some 50 (autonomous) industrial research associations.
3. Encourage scientific and technological advances in British industry. This is the other side of the coin described in item 2. Organs capable of dealing with this problem are virtually the same:
   —National Research Development Corp.
   —Industrial research associations.
   —Special research bodies in technology and more widely the research stations.
   —Industrial economic development councils.[61]

Early interpretation of the Ministry's mission pointed toward a dramatic across-the-board approach for improving Britain's economic condition. In the process the Government was perhaps overly optimistic about the speed at which "fallout" would occur. At the same time, the Ministry inherited a host of institutions that already had specific orientations and used preferred approaches. It is this diversity of approach within an administrative whole which best characterizes the Ministry today.

The attempt to speed the science to sales process is embodied in cooperative research, and development assistance programs as well as the activities of industrial liaison centers and industrial research associations.

Cooperative research institutes serve the needs of specific industries or specific technologies. In many ways they are functionally similar to agricultural research stations and advisory services. In 1963 these institutes received $32.5 million, 19 percent of which was supplied by the Government. One-fifth was directed toward basic research, one-half toward applied research, and the remainder largely for services.

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[61] Wilson, Harold, "Science, Industry and Government," Nature, Apr. 17, 1965, pp. 231-232.

b. The National Research Development Corporation

Development assistance programs are executed by the National Research Development Corporation. In a unique way the British have institutionalized entrepreneurism. An independent "public" corporation, NRDC is financed by the Ministry of Technology with Government grants. NRDC is designed to promote the adoption by industry of new products and processes invented in governmental laboratories, universities, and elsewhere. It advances money where necessary to bring new ideas to a commercially viable stage.

The Corporation "underwrites" industry to promote inventions that the private sector would find either too costly, too risky or that would take too long to develop. For inventions that are successfully exploited, NRDC expects in return to receive a share of the profits.

Although some successes are recorded, the record of the NRDC from July 1, 1961, to March 31, 1966, shows that $23,795,650 have been invested with a net loss of $15,386,250.[62] It may be that the early operations were experimental and the concept will ultimately prove to be a financial success. Some observers believe that the Corporation is under considerable pressure from Government research laboratories to promote technology which has a relatively low utilization potential, having already been passed over by the private sector.

Development assistance has covered a wide range of technologies. Projects in computers, fuel cells, flexible oil barges, pharmaceuticals, cryogenic engineering, diesel engines, variable speed gears, potato harvesters, phototypesetters, and others have been sponsored. Perhaps the most spectacular is the Hovercraft, a ground-effects machine whose development into a transportation vehicle led to the formation of a new private corporation—Hovercraft, Ltd.

c. Industrial Liaison Centers

Industrial liaison centers provide a means for the Ministry of Technology to foster economic and social development while, at the same time, to gather information on obstacles to technological innovations and on the needs of industry for technical support. Industrial liaison officers work out of the centers which are based at colleges of advanced technology and regional and area technical schools. The officers are charged with the responsibility to establish and maintain a dialogue between industry, the Government and the universities. Because an increase in industrial productivity is the current goal of the British Government, technology transfer is being concentrated on the large firms which have a major impact on the foreign trade position. Contact is made with the local firms to inform them of governmental and university services that are available. At the same time, by analyzing the problems of a particular firm the officers can identify specific needs and direct pertinent information to the firm. The advisory facilities of the university related to research, development, production, and design are an important element of the service provided.

d. Industrial Research Associations

Another activity of interest is the industrial research associations. A total of 48 were supported by the Ministry of Technology for a cost

[62] National Research Development Corporation, 17th Rept. 1965–66, London: Her Majesty's Stationery Office, 1966, p. 12.

of $10 million in 1966. These associations form a mechanism for exchanging information, providing library services, and organizing conferences within a specific industry. For example, the British Iron & Steel Industry Translation Service (BISITS) is a cooperative venture that has brought together the major iron and steel companies of the United kingdom, the Iron & Steel Institute, and the British Iron & Steel Research Association (one of the Ministry-supported associations).

Computers, standards, and machine tools are technologies that the Ministry has placed high on its priority list. A National Computer Center was established to provide services to all industry, commerce, and local authorities to improve programing techniques, make them more widely and easily available, and increase the supply of the special skills required.

A refinement of present standards of measurement and a shifting from the English to the metric system are being encouraged by the Ministry, not only for domestic economic reasons but for the improvement of England's competitive position internationally.

4. FRANCE

In France the supreme body for policy planning in science and technology is the Ministerial Committee for Scientific and Technical Affairs. Its job is to coordinate the research and development expenditures of the various branches of Government. The Minister of Scientific Research and Questions of Nuclear and Space Research is also at the ministerial level and a member of the committee. The interministerial committee is assisted by the Advisory Committee for Scientific and Technical Research, which is composed of 12 scientists. These committees have a joint secretariat, the General Delegation for Scientific and Technical Research (DGRST). It is the Government's general staff for the conduct of science policy but also has its own budget for operating programs.

a. National Center for Scientific Research

Despite the rather elaborate network, France has only recently taken steps to foster technology transfer from the governmental to industrial sectors. One focal point for this activity is the National Center for Scientific Research (CNRS). The Center's function is to provide funds for fundamental research to universities and independent research institutes established by it. Shortly after the French finished their study of the NASA technology utilization program in early 1966, Science Minister Peyrefitte proclaimed the need for a similar program in France. In the proposal that resulted, a National Agency for Research Evaluation (ANVAR) would be affiliated with CNRS. ANVAR would be financially autonomous and industrial and commercial in character. This Agency would cooperate in the evaluation of the results of scientific and technical research carried out by public services and enterprises, particularly laboratories associated with universities and CNRS. It would be able to lend the same cooperation to isolated inventors and enterprises in the private sector, after a favorable recommendation from the Committee on Inventions which would report to ANVAR. In this way it would seek to establish all the necessary operations for development and evaluation of these inventions, excluding industrial utilization operations themselves.

Another function of CNRS is to act as a documentation center by supplying scientific and technical documents, by issuing abstract bulletins and reviews, and by providing translations and library services.

b. Development contracts

Risk sharing by the French Federal Government with firms carrying out development work was relatively small until recently. Between 1957 and 1965, 50 development contracts were partially financed by the Ministry of Industry. These contracts are made with industrial firms for development work in areas where the Government is not the primary customer and where opportunities for innovation are favorable. Beginning in 1965 money was budgeted to the General Delegation for Scientific and Technical Research for engaging in development contracts with private industry on behalf of the state. From an original amount of $2 million the fund was expected to increase greatly in the future.[63]

c. New technical activities

Several new technical activities were launched during the course of the last general plan (fourth plan, 1961–64). The purpose is to support technical research sectors where the ground would not be broken but for the intervention of the state. The 10 areas targeted for under the fourth plan, at an initial cost of $75 million, include research in mechanical engineering, building and public roads, and macromolecular chemistry.

B. THE UNITED STATES AND WESTERN EUROPE—RESEARCH AND DEVELOPMENT IN THE CIVILIAN SECTOR

Frequently, one or another variation is heard of the theme that our country is not committing enough research and development funds to the civilian sector. Sometimes it is asserted that this lack of attention is occasioned by too heavy an R. & D. commitment to space, atomic energy, and military purposes. In one way or another, these observers conclude that the United States is not maintaining its technological competitiveness with the other industrially advanced nations of the world.

On January 26, 1967, Dr. Paul Grogan, Director, Office of State Technical Services, Department of Commerce, in a statement before the Special Subcommittee on the Utilization of Scientific Manpower of the Senate Committee on Labor and Public Welfare said that:

> Technological change abroad has increased foreign competition: As foreign industry becomes more selective in the application of new technology to produce goods used in the civilian economy, competition becomes more intense and displaces American goods, jobs, and business opportunities.
>
> Comparable emphasis is lacking in this country with respect to the use of advanced technology to produce goods for consumer markets at home and abroad.[64]

On the other hand, the report, "Technological Innovation: Its Environment and Management," released by the Department of Commerce in February 1967 and prepared by its Panel on Invention

[63] "Government and Technical Innovation," Organization for Economic Cooperation and Development, Paris, 1966, p. 24.

[64] Statement by Dr. Paul Grogan, before the Special Subcommittee on the Utilization of Scientific Manpower of the Senate Committee on Labor and Public Welfare, January 26, 1967, stenographic transcript of hearings, Vol. No. 3, p. 207.

and Innovation, referred to the "technological balance of payments," a term introduced by the Organization for Economic Cooperation and Development in their report, "The Research and Development Effort in Western Europe, North America, and the Soviet Union." (Also discussed in the section on the technology gap, p. 49). The effects of technological change on international trade were considered a persuasive reason why the Federal Government should be concerned about the promotion of invention and innovation. The Panel noted that:

> The OECD compilation shows the United States receiving roughly 10 times as much in technological payments from abroad as goes out in payments to other nations. This is a very significant secondary effect of innovation in the American economy.[65]

On the basis of a comparison of research and development funding in the United States and Western Europe it can be shown that in absolute as well as in relative terms the U.S. effort in the civilian sector is more substantial than the Western European effort. Table 5 presents figures and percentages brought together from two tables in the OECD study. In 1962, the latest year for which comparative statistics were available, the United States had a gross expenditure on research and development (GERD) more than four times greater than the combined total of Belgium, France, Federal Republic of Germany, the Netherlands, and United Kingdom. In terms of GERD as a percent of GNP the United States invests twice the percentage of the European countries.

[65] "Technological Innovation: Its Environment and Management," U.S. Department of Commerce, January 1967, Washington, D.C., U. S. Government Printing Office, page 5.

TABLE 5.—*Estimated gross expenditure on research and development (GERD), gross national product and participation by economic sector United States and selected Western European countries, 1962*[1]

Country	GERD (millions of U.S. dollars)	GNP at market price (millions of U.S. dollars)	GERD as percent of GNP	Performance			Source of funds		
				Business enterprise sector (percent)	Higher education sector	Government and non-profit sectors	Business enterprise sector	Higher education sector	Government and non-profit sector
United States	17,531	557,590	3.1	71	10	19	35	2	63
Western Europe (Belgium, France, Germany, the Netherlands, United Kingdom)	4,360	267,200	1.625	59	12	29	43	X	57
Belgium	133	13,000	1.0	65	13	22	63	X	37
France	1,108	72,500	1.5	48	14	38	30	[2]	70
Germany	1,105	88,900	1.3	61	20	19	60	X	40
Netherlands	239	12,800	1.8	60	14	26	65	X	35
United Kingdom	1,775	80,000	2.2	63	5	32	36	X	64

[1] Table adapted from statistics in C. Freeman and A. Young, "The Research and Development Effort in Western Europe, North America and the Soviet Union." Organization for Economic Cooperation and Development, Paris, 1965, pp. 71, 72.

[2] Included in government sector.

Looking at the figures by source of funds, Western Europe is slightly ahead in the percentage supplied by the business sector—43 percent for Western Europe to 35 percent for the United States. When these percentages are converted to total dollars, however, the civilian sector of the United States outspends the civilian sector of Western Europe by a ratio of 3.3 to 1—$6.15 billion for the United States as compared to $1.87 billion for Western Europe. Relating these figures to total GNP, the ratio is 1.6 to 1 in favor of the United States.

A final comparison can be made by total performance in the civilian sector. Disregarding the source of funds, $12.45 billion was spent in the civilian sector in the United States in 1962, while $2.56 billion was spent in the civilian sector of Western Europe for a ratio of 4.9 to 1 in favor of the United States. Relating these figures to total GNP, the ratio is 2.3 to 1.

Thus, the United States, despite its large expenditures for military-space R. & D., supports its civilian industrial economy with science and engineering funding to a much greater extent than does Western Europe. The result of this heavy commitment to industrial R. & D. is to provide a favorable flow in the balance of payments to the extent that other countries license or buy U.S. technology. Certain fields can be selected where foreign concentration of efforts have produced severe competition for U.S. firms (for example, steel, glass, plastics and organic chemicals). On the other hand, talk of a technology gap suggests the European nations feel technologically inferior to the United States in a number of areas. Overall, there is no question of the relative technological strength of America.

C. The U.S.-European Technology Gap

Foreign Minister Amintore Fanfani of Italy raised the question of a technology gap between the United States and Europe at a May 1966 ministerial meeting of the North Atlantic, Treaty Organization. The assertion was that Europe lags behind the United States in technological prowess and that the gap was steadily increasing.

The gap exists, it is postulated, because the United States is spending more than Western Europe on research and development. The new technology that results produces a commanding market position and a higher economic growth rate. It is argued therefore, that unless the United States assists Europe to reduce its technological inferiority, Europe will suffer economically and be less strong as a Western ally.

(Similar arguments are heard from some regions of the United States which maintain that the imbalance in the geographical distribution of Federal research and development funds retards the economic growth rate in regions that receive less than their proportional share. The debate revolves around the question of the relationship between research and development and economic growth, as compared to other factors affecting growth rate; e.g., managerial ability and fiscal incentives.)

As a counterargument it can be shown that the annual growth of the total output of the United States is lower than other Western countries which are not so rich in technology as is the United States. In particular, the United States and Canada are the lowest of Western countries on the basis of rate of growth per capita. However, this simply means that the United States is far in advance of other Western countries in standard of living. For instance, North America, with 6.9 percent of the world population, has 31 percent of the real GNP compared with industrial Europe which has 8.6 percent of the world population and 25 percent of the real GNP.[66]

Subsequent to the ministerial meeting, Fanfani emphasized the relation of technology to economic growth and proposed a "technological Marshall plan" to bridge the widening gap. Whereas, the highly successful Marshall plan was entirely financed by the United States, the Fanfani proposal would encourage European investment in research and development. Nevertheless, the United States would be asked to make available the fruits of technological advance in six fields suggested for cooperative efforts—electronic computers; aeronautics; space research; space satellites for scientific, industrial, and commercial use; atomic and general energy research; and water desalination and pollution control technologies.

President Johnson responded on October 7, 1966, by agreeing to study the proposal carefully, and asserted that, "The United States is ready to cooperate with the European nations on all aspects of this problem."[67]

On November 26, 1966, the White House announced the appointment of Donald F. Hornig, the President's Special Adviser for Science and Technology, as chairman of an ad hoc committee to study the issue and find ways to overcome the disparities. (See p. 99 for Dr. Hornig's views on technological change.)

While the implication of the President's speech is that a gap does in fact exist, there has been much debate over the degree, and even whether, instead, many gaps exist favoring various nations in different ways. In certain technologies, e.g., metallurgy, steel, and shipbuilding, it has been noted that the United States is, to an extent behind other countries. The continuing arguments over the General Agreement on Tariffs and Trade suggest that technological superiority is not always in favor of the United States.

It has been noted that a "technological Marshall plan" may be one of many approaches to enhance the alliance in the Atlantic community. With an ailing NATO, this may be one way of stressing the need for a thorough restudy of the objectives of the alliance—political and economic as well as military.

Former Secretary of Commerce John T. Connor viewed the problem in a different way at a seminar on Technology and World Trade held in November 1966. He stressed the point that a "management gap" is often the primary problem which provides obstacles to the application of technological know-how.

Participants in the seminar, including several Europeans, generally agreed. Dr. H. B. C. Casimir, director of research laboratories, N. V. Phillips Industries, the Netherlands, preferred to use the term "organization gap." He said that even if the United States had a political composition similar to Europe's—five or six official languages, several minority groups within each state, and tariff boundaries between states—it would still take Europe 10 to 50 years to bridge the gap.

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[66] Maddison, Angus, "Economic Growth in the West," the Twentieth Century Fund, New York, 1964.

[67] "Presidential address before the National Conference of Editorial Writers," Oct. 7, 1966, Weekly Compilation of Presidential Documents, vol. 2, No. 40, Oct. 10, 1966, p. 1425.

While the Fanfani proposal crystallized the technology gap issue, its emergence began before that. The report, "The Research and Development Effort in Western Europe, North America and the Soviet Union," released by the Organization for Economic Cooperation and Development (OECD) in December 1965, provided a statistical comparison of R. & D. efforts between these three regions. The report highlighted the numerical superiority of the U.S. research effort. Statistics on manpower resources and R. & D. expenditures illustrating the greater scope of American activity.

The report attempted to measure the effectiveness or productivity of research and development by comparing each country's "technological balance of payments." The term refers to payments and receipts between countries for technical know-how, licenses, and patents.

The ratio of payments to receipts for the United States was well below one (a favorable balance); the ratio for European countries was above one (an unfavorable balance). The figures are: United States (1961)—.1; France (1962)—2.7; Germany (1963)—2.7. The ratio of Western European transactions with the United States alone is even higher—5.6 in 1961. In other words, Western Europe paid the United States $5.60 for every dollar which the United States paid them in the exchange for patents, licenses, and technological information. The report concluded that some indications of the American lead, as evidenced by the introduction of advanced techniques and the attainment of higher levels of productivity in the civilian sector as well as the greater allocation of resources to research and development over a long period of time, are provided by information on the technological balance of payments between the United States and Western Europe, and by patent statistics.[68]

Lawrence C. McQuade, Assistant Secretary of Commerce, in an April 1967 speech on the transnational facets of technology quoted recent figures on the technological balance of payments. In 1965, the United States earned $614 million from all other countries as compared to the $138 million that was paid out. The ratio in favor of U.S. was 4.5. He stressed that technology, "by raising productivity and lowering costs per unit of production, helps American industry compete more effectively in world markets."[68a]

The question of the technology gap arose only a month later, in January 1966, at the Second Ministerial Meeting on Science sponsored by OECD. In answer to European desires for cooperation with the United States in order to close the gap, Dr. Hornig, the U.S. representative, replied, in part, that an essential ingredient in the technology to productivity cycle is an environment which encourages innovative application.

Secretary of Defense McNamara has stated, "* * * I believe that the technological gap is misnamed. It is not so much a technological gap as it is a managerial gap. And the brain drain occurs not merely because we have more advanced technology here in the United States, but rather because we have more modern and effective management." (Address at Millsaps College, Jackson, Miss., Feb. 24, 1967.)

Op. cit. Footnote 1, Table 5, pp. 74–5.

[68a] McQuade, Lawrence C., "That Troublesome Transnational Technological Tiger," speech before the Western Regional Conference on Science, Industry, and Law in Transnational Business Transactions, University of Denver Law Center, Denver, Colorado, April 21, 1967, p. 3.

While the United States stand was a combination of concern and skepticism, the Soviet Union tried to take advantage of the issue for its own purposes. Premier Kosygin, during his warmly received visit to France in December 1966, accused the United States of trying to dominate Western Europe through international science cooperation. He enjoined European scientists and engineers not to add to the "brain drain" problem and called for greater technological cooperation between the Soviet Union and France.

Currently, there are at least four studies in progress designed to provide a firmer base of data and a more comprehensive analysis of issues from which judgments on the nature of the gap will be made. NATO, OECD, the Common Market, and the Hornig Committee are expected to make recommendations in the near future which will be predicated on the severity of the gap as each group interprets it. Particularly within NATO and OECD the search is on for institutional forms suitable for attacking the problems involved.

One recent article viewed the technological Marshall plan as an impractical concept.

> The underdeveloped nations would certainly have first call on any American effort on that scale. And besides, American industry would doubtless view a latter-day Marshall Plan for Europe as suicidal altruism.[69]

Yet it has also been stressed that:

> Whether the gap is real or chimerical, Europe's most important politicians believe in its existence. It is therefore, a political fact to be reckoned with, one that has political consequences.[70]

The technology gap presents an interesting problem in forming policy for technology transfer. The issue is this: if the U.S. Government supports extensive efforts to disseminate technology from Federal R. &. D. programs to American industry, to what extent would these same efforts be available to foreign business firms? What restrictions should be placed on subscribers to government dissemination services? Or conversely, if the United States agrees to participate in a technological Marshall plan, would the information come from Federal agencies? Would the United States in turn be able to draw on European technology?

NASA has a foreign licensing program for patents which it holds. Foreign patents are being acquired to control the exploitation of U.S. Government sponsored technology in other countries. Firms holding nonexclusive licenses from NASA in the United States may be given exclusive licenses in 11 different foreign countries. Since foreign licenses will not be royalty free, foreign firms may be licensed exclusively in exchange for a royalty to the U.S. Government to help offset research costs.[71]

One of the problems with patents and with nonpatentable information, publicly or privately held, is that the Government regulates the export of technical data under the Munitions Control Act and the Export Control Act. The Department of State administers the Munitions Control Act by requiring an export license for all technical data with military utility that is destined for free world countries.

[69] Walsh, John, "NATO: A North Atlantic Technology Organization," *Science*, Feb. 24, 1967, p. 988.
[70] Nossiter, Bernard, "U.S. Gets Too Smart for Europe's Good," Washington Post, Feb. 12, 1967, p. E1.
[71] Parker, Gayle, "The NASA Domestic and Foreign Licensing Programs," Technology Utilization Forum, vol. 4, No. 9, Feb. 1, 1967, NASA, Washington, D.C., p. 4.

Previously published data and those included on a list of exemptions are excluded from the licensing procedures. The Department of Commerce administers the Export Control Act in an effort to control the export of technical data to Communist countries. Nonmilitary technical data destined for a Communist country must be licensed. Nonmilitary data to be sent to free world countries do not require licensing and requests are not scrutinized unless the possibility exists that a Communist country will be the ultimate recipient.

There appears to be nothing to prevent free world countries from becoming users of technology transfer services such as the Aerospace Research Applications Center, for example. Yet, at the same time, it seems that the United States should not freely make available to foreign countries the results of research and development paid for with public funds.

Some knotty problems are evolving as technology is recognized as a tangible resource in international economic competition and a possible instrument of foreign policy. Science has always proceeded under the assumption that research results were to be freely and widely distributed when they did not compromise national security. International patent agreements have protected the value of inventions. But the gray area of technology, not simply facts and data and yet not patentable, is a subject for considerable discussion.

VII. ECONOMIC FACTORS IN TECHNOLOGICAL CHANGE

This section of the report describes the process of technology transfer and its relation to economic activity and public policies. The subject is complex and new enough so that a diversity of opinions exists in many areas. Studies have been made from the empirical approach of examining case histories and correlating statistics of invention and innovation with economic indicators. Other studies proceed from a theory of industrial development to induce and predict the role of new technology. Technology transfer is a social science phenomenon and will not be understood with the precision that can be brought to problems in the physical sciences or engineering. Disagreements on interpretations and cause-and-effect relationships often cannot be resolved with available data. There are few opportunities for short-term conclusive experiments. Thus, policy planning for technology transfer is different from, and more difficult than, space exploration or high energy physics.

A. Premises

1. ECONOMIC GROWTH IS A NATIONAL GOAL

In order to confine this study to reasonable dimensions, certain premises are adopted. First, economic growth on a national scale is assumed to be desirable. The rate of this growth should be greater than the population increase to enable the United States to improve the standard of living for its own citizens and to meet the mounting requirements of world leadership. Economic growth occurs in several ways, among them being increased productivity and the addition of new products, processes, and services. These growth factors depend on new technology which brings changes in the makeup of the economy.

One of the major effects of new technology is the reorientation of supplier-purchaser relationships among industries. For example, the increased use of plastics in automobiles means that the same product is made from different material. The plastics producers benefit at the expense of metals. Another example is the "invasion" of the copying field by xerography which is threatening conventional copying equipment. The net results to the economy of such changes is hard to predict.

Negative effects of technological change are most commonly thought of as unemployment because of automation or occupational obsolescence. Feather bedding is a defensive reaction to the replacement of labor with machines. These social problems can be mitigated by advance planning and reeducation. The long-range result of automation can be a redistribution of the labor force into higher skills.

The depersonalization which accompanies high productivity can bring a degradation of quality values in goods and services. There is a vestige of Luddite thinking in some attitudes and reactions to technological change.

Technological change also may detract from economic growth by substituting new goods or services with less economic worth for old, or by social costs such as deaths and property damage from the automobile. Nevertheless, technological change has had a great net beneficial effect on economic growth, despite specific problems in some areas.

2. TECHNOLOGICAL CHANGE IS DESIRABLE

The premise of fostering technological change implies that the availability of scientific research and development results must be adequate to the needs of industry. Change via new technology means the acquisition of facts and know-how by industry. The technology is new to the user, not necessarily new in the sense of having just been created. New technology may be acquired by performing directed experiments suggested by the recognized application needs, or by selecting the useful knowledge from the reservoir of previously performed research and development.

Technological change is mainly concerned with innovation—the risk-taking step of introducing inventions or ideas into the economy. Successful innovations then diffuse into other industries and uses.[72]

While new technology is the essential first step in technological change, it may represent only 5–10 percent of the total investment in a new product or process. It is estimated that subsequent costs are divided: engineering, 10–20 percent; tooling, 40–60 percent; manufacturing, 5–15 percent and marketing, 10–25 percent.[73]

The magnitude of the risk depends on the market assumptions made by the entrepreneur, and the quality and quantity of technology available to him.

3. MEANS OF ACQUIRING NEW TECHNOLOGY

As science and engineering have developed, the complexity of research projects in equipment and manpower has tended to increase the minimum size (or critical mass, to borrow a concept of nuclear physics) for an efficient laboratory operation. This investment may be too much for many firms. Even large industrial research laboratories do not contain expertise in every field of science. Further, the great variety of science which may contribute to (or be necessary for) a complete innovation precludes the direct experimental acquisition of all the facts. It is economically imperative that existing knowledge be used to the fullest. The expense of obtaining knowledge by transfer should be considerably less than the cost of directed research. But the costs of packaging and transporting technology are not zero, and the quality of the technology may not be known with confidence. In any event, transferred technology is now considered along with research-acquired technology as a significant source for the process of technological change.

4. INFORMATION SYSTEMS WILL BE DEVELOPED

Technology may be confused with scientific and technical information. What is transferred is, of course, information. And the

72 Holloman, J. Herbert. Technology Transfer, Address before the Conference on Technology Transfer and Innovation, National Planning Association, Washington, D.C., May 16, 1966.
73 Op. cit., ref. 65.

developing mechanisms and organizations for handling technical information are basic to the technology transfer process. Much technology is included in research reports, scientific papers, drawings, specifications, performance reports, economic analyses, and the documentation of hardware and process development. But much technology also remains unreported and perhaps unrecognized as the "know-how" derived from applying science. For example, technology is the technique of welding two dissimilar metals by use of a special flux. This item of technology might be incidental to some R. & D. project and not be described or disseminated by any conventional information system. But the welding technique could also quite likely be used by other applied research and development workers at another time.

With respect to the technological information to be processed, the premise is taken that the current efforts by the Committee on Scientific and Technical Information of the Federal Council for Science and Technology will bring about an integrated national document handling system. The goal of this system would be to assure "the existence within the United States of at least one accessible copy of every significant publication in the worldwide scientific and technical literature.[74] [75] The timetable is contingent on the selection of a system design, and provision of the money and manpower to implement it. In the meantime, current and evolving centers and networks will serve specialized science and technical information areas. The Federal responsibility for a system seems to be an accepted national policy.

The responsibility of the researcher to communicate has always been a cornerstone of the scientific method. A panel of the President's Science Advisory Committee made this point in the Weinberg report (named after Dr. Alvin Weinberg, Oak Ridge National Laboratory, the committee chairman). The panel was mainly concerned with the handling of scientific and technical information, but succinctly stated the case for identifying and reporting new technology:

> Transfer of information is an inseparable part of research and development. All those concerned with research and development—individual scientists and engineers, industrial and academic research establishments, technical societies, Government agencies—must accept responsibility for the transfer of information in the same degree and spirit that they accept responsibility for research and development itself. The technical community generally must devote a larger share than heretofore of its time and resources to the discriminating management of the ever-increasing technical record. Doing less will lead to fragmented and ineffective science and technology.[76]

The recommendations of this PSAC report are being carried out for scientific information. A successful technology transfer program will require that this reporting concept be extended to the new technology generated by Federal R. & D., the results of which usually are not included in conventional scientific papers and reports.

A scientific information system will be a valuable adjunct to technology transfer. The mechanics developed will be applicable to technological as well as scientific information. The system will not,

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[74] Carter, Launor, "National Document-Handling Systems in Science and Technology," Science, Dec. 9, 1966, p. 1299.

[75] Federal Council for Science and Technology, "Recommendations for National Document Handling Systems in Science and Technology," PB 168267, Clearinghouse for Federal Scientific Information, Springfield, Va.

[76] *Science, Government, and Information.* Report of the President's Science Advisory Committee, Jan. 10, 1963.

at first, contain all of the technology but could accommodate it eventually as identification and reporting is expanded.

As far as the consumer of technical knowledge is concerned, technology transfer is proving to be a new information source, related to but not a substitute for, conventional science information.

5. THE RELEVANCE OF NEW TECHNOLOGY

Generalizations about technology transfer are as misleading as about any other subject. It should be understood that while new technology is important to industrial growth, not all new technology is relevant and not all industries are highly dependent on science. The nontechnological factors are often the most important in preventing or br nging about a new product. There are cycles of industrial change which seem to have little to do with invention. Much of Federal science and technology is concerned with environments and stresses which have little to do with civilian requirements. Successful technology transfer occurs within the overlapping region where existing facts and know-how answer recognized needs and demands. The amount of overlap or relevance differs from industry to industry and between scientific fields.

Lesher and Howick, writing for the National Commission on Technology, Automation, and Economic Progress place the relevancy of Federal R. & D. results in this perspective:

> Critics of existing programs to transfer technology from one industry or one discipline to another generally state the proposition this way: "If we spent billions of dollars to develop better home appliances, would we, in the process, get a man to the moon or build a better ballistic missile?"
>
> The answer, obviously, is "No." But the wrong question has been asked.
>
> Rephrasing the question to recognize the nature of R. & D. efforts of NASA, AEC, and DOD, we would ask: "If we spent billions of dollars in research and development in every scientific and engineering discipline, is it likely that the new knowledge thereby generated might find wide applicability in helping to meet the problems of an industrialized society?"
>
> Now the answer, obviously, is "Yes." [77]

The central question in putting money into purposeful transfer programs is whether there is enough relevance to make it worthwhile. The alternatives are to rely on demand-directed original research for the answers and let transfer occur randomly at an indeterminate rate.

6. THE AMOUNT AND LOCATION OF AVAILABLE TECHNOLOGY

It is difficult to conceive that mankind could have too much knowledge. Every additional known fact increases his capability to solve problems or meet contingencies. Therefore, the premise is made that all technology has some potential in serving society, whether in commerce or for public purposes. In considering the business sector in the United States, it might be argued that the $58 billion which private industry invested in R. & D. for its own benefit during the past decade has been sufficient. The Nation has progressed and has competed successfully in world markets. On this assumption the $99 billion investment by the Federal Government in new technology for its purposes could be said to be excess to any needs of industry. Another argument for technological saturation of the economy is that

[77] Lesher, Richard L. and Howick, George J., "Assessing Technology Transfer," NASA SP-5067, National Aeronautics and Space Administration, 1966, p. 24.

venture capital is limited as well as the personal interests and efforts of entrepreneurs. Large companies are reported to provide funding and management guidance for only a few innovations each year even though others seem equally good risks. Despite these admitted indications of technological opulence, the Federal research funds are estimated to generate several hundred thousand fragments of new technology each year. (See p. 9.) The enormity of this accumulated reservoir of knowledge makes it a national resource worth considerable effort to tap.

7. NEED IDENTIFICATION AND INNOVATION

Joseph A. Schumpeter stated long ago: "As long as they are not carried into practice, inventions are economically irrelevant.[78]

If it is true that the availability of scientific and technical information is not the pacing item in innovation, what are the implications for technology transfer? Evidence is mounting that the pressure of new technology has little effect on the rate of invention and innovation. Rather it is demand which pulls on science and engineering for answers.

Jacob Schmookler has studied the variations over long-time periods of inventive activity and industrial growth in a number of fields. He finds that patents are a reasonable indicator of R. & D. effort. The number of patents in a given field rise and fall with the sales of products in a closely coordinated manner. But the patent curve lags behind and does not precede the sales curve. When sales begin to rise and an industry expands, the rate of patenting in that technology increases a short time later. When sales fall the rate of invention soon tapers off.

The most reasonable explanation for the relation, an explanation consistent with the kinds of stimuli that lead men to make important inventions, is probably the simplest. It is that (1) invention is largely an economic activity which, like other economic activities, is pursued for gain; (2) expected gain varies with expected sales of goods embodying the invention; and (3) expected sales of improved capital goods are largely determined by present capital goods sales.[79]

These economic studies lead to an economic theory which suggests that deficiencies in economic growth via technological change are more related to inadequate identification of demands and choices among conflicting wants and needs. The long held impression that science stimulates invention is relegated to a secondary importance by this analysis.

8. TECHNOLOGY TRANSFER EFFORTS ARE WORTHWHILE

In a 1963 study, the Denver Research Institute concluded that intangible spinoff is more important than the obvious transfers of complete packages of technology such as jet aircraft or computers. According to their report, spinoff can be profitably exploited by many companies and is a stimulus to economic growth.[80]

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78 Schumpeter, Joseph A., "The Theory of Economic Development," Harvard Economic Studies, XLVI Harvard University Press, Cambridge, 1934, p. 88.

79 Schmookler, Jacob, "Invention and Economic Growth," Harvard University Press, Cambridge, 1966, p. 206.

80 Welles, John G., and Robert H. Waterman. "Space Technology: Pay-off from Spinoff," Harvard Business Review, July–August 1964, p. 106.

Dr. Frederick Seitz, President of the National Academy of Sciences, comments:

> The topic of spillover from space research was a matter of lively discussion several years ago and has frequently been regarded as a joke since. It seems to me that this levity is unwarranted. Really profound innovations take time to assert their influence. The automobile, the airplane, and the radio were the butts of jokes in their early phases. The benefits which the United States has gained as a result of emphasizing digital computer technology between 1945 and 1960 are not regarded as jokes by the Europeans, who now find themselves at a disadvantage in this field. No one who believes that reliability and managerial effectiveness are to be taken seriously should write off the revolutionary potentialities associated with the space program too quickly.[81]

Therefore, when considered in the total context of the Nation's economy, technology transfer is judged to be worth considerable effort. The rationale is summarized as follows:

1. When demand or recognized need does stimulate invention, the knowledge produced in the past limits the state of the art within which invention must occur. So the technology at the disposal of the applied researcher determines how fully demand will be met.
2. The total reservoir of knowledge is likely to be applicable to many industries since almost all industries are becoming more diversified in their products and services, and since each product or service involves many bits and pieces of technology.
3. The new technology arising from Government directed research is unlikely to become easily available to industry without a specific effort in transfer.
4. Federal control of $99 billion worth of technology over 10 years suggests Federal responsibility to get the most good out of this resource. Additional tangible returns on the investment may be realized in other Government programs as well as in increased corporate taxes from economic growth. Of tangible benefits to the Nation are an increased standard of living and international power and prestige from industrial strength.

B. Barriers to Technological Change

1. THE CLIMATE FOR INNOVATION

There are rather obvious and considerable financial and technical barriers to the acceptance of new technology and to technological change itself. The technology may cost too much to acquire, the subsequent development may seem too expensive or disruptive, and the relevance may be obscure. The firm may be doubtful that any governmental bureaucratic talent could be helpful to business; or suspicious that consultants and transfer agents might carry away trade secrets. But more important are the barriers of the "climate" within which innovation takes place. Dr. Charles N. Kimball, president of Midwest Research Institute, suggests that corporate management, the scientific community, and universities are responsible for "outdated institutional practice, lack of entrepreneurship, and of reluctance to accept new ideas and new practices."[82] Philip Wright, in a

[81] Seitz, Frederick, "Science and the Space Program," Science, June 24, 1966, p. 1720.
[82] Quoted in Lesher and Howick, op. cit., ref. 81, p. 39.

study for NASA at the University of Maryland, has identified the following difficulties in the commercial utilization of new technology:

The discouraging effect of abortive reviewing of technical information.
Difficulties of evaluating advantage.
Difficulties of assimilation.
Inhibiting effects of companies' new, idea receptial [sic] procedures.
Cheerless effect of the high cost of evaluation.
Frustration owing to delays in response to questions.
The impediment of the difficulties of locating.
Adverse effects of inadequate disclosures.
Adverse results of unfavorable economics.
Barriers owing to educational deficiencies.
The obstructing consequences of inadequate finances.
Adverse influence of Government policies.
Obstructions owing to impractical nature of innovations.
Difficulties owing to inappropriate orientation of the presentation of technical information.
Discouraging effects of limited applications.
Inhibiting effects of the absence of information about applications.
Hampering situations created by company disinterest in nonexclusive licensing.
Adverse effects of inability to devote time to evaluation.
Deterrent effect of obsolescence.
Impending outcome of weak patents.
Handicaps due to poor communications.
Deterrent effect of proprietary design ownership.
Obstructing impact of security regulations.
Preventative effects of fear of lawsuits.[83]

A purposeful transfer program must include efforts to overcome these social environment effects or even the best identification and dissemination system will be ineffective.

2. THE PUBLIC UNDERSTANDING OF TECHNOLOGICAL CHANGE

The climate for innovation involves the management response to the individual entrepreneur. It is apparently not true that the world will beat a path to the door of the inventor of a better mousetrap. The successes and failures of technology transfer will depend to a great extent on the receptivity of society to new ideas. Carl E. Barnes describes the importance of management attitudes toward the innovator:

Selling research developments requires skill, persistence, and courage. I emphasize courage because there is always danger of failure and the consequent damage to one's reputation. In most companies I have known, the man who is associated with a research failure is rarely given a "plus" from top management for his effort, so far as advancement is concerned.

To my knowledge, there has never been a successful new product put on the market which did not have its "product champion"—someone who risked his reputation, or possibly even his job, to put it over.

Management which wants to succeed in increasing the productivity of its research operation must always be aware of the essential role played by the product champion. And it must see to it that the barriers he encounters are not insurmountable. There must be barriers, of course, for they constitute the screening operation which separates good projects from poor ones. But in many companies these barriers are so formidable that good developments are lost—due either to lack of courage or incentive, or both, on the part of those who must sell those developments to management.[84]

Many modern corporations are torn between the belief that innovation is essential to their growth and the fear of the uncertainties which

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[83] Ibid. p. 40–41.
[84] Barnes, Carl E., "To Promote Invention," International Science and Technology, December 1966. p. 67.

go with new ventures. Technology may not be recognized as a primary ingredient in decisions which are made by business management, but it underlies the entire process. Donald A. Schon writes:

> In the process of innovation, everything is done to permit decision on the basis of probable dollar costs and dollar benefits. In the process, the corporation converts the language of invention to the language of investment. Instead of talking about materials, properties, performances, experiences, experiments, and phenomena, the corporation talks of costs, shares of market, investment, cash flow, and dollar return.[85]

In summary, there is a difference between general recognition or awareness that science and technology are important and the realization that a particular critical need exists. This difference is what a technology transfer program can demonstrate to business management.

3. PROPRIETARY RIGHTS

In considering the proprietary aspects of technology it is generally acknowledged that the organization performing the research and development cannot capture all the benefits, nor prevent other groups from taking advantage of the knowledge without compensating the risk-taking firm. The rights of the researcher, inventor and innovator are guarded to various extents in order to encourage exploratory work by assuring some control of the profits but the protection is incomplete, especially as time goes on. Proposals for technology transfer must balance the need for wide dissemination against the necessity for proprietorship. Some protection to the developer is necessary to justify the additional expense in moving the technology to the point of sales and social-economic benefit. Of course the major advantage which the entrepreneur gains by his willingness to take risks is simply the head start in time over potential competitors. This favorable position can often be maintained throughout development, production, and marketing as constant improvements are introduced. But smaller firms may not be able to afford the pace of rapid, competitive development and thus a limited period of exclusive use may be essential.

a. Scientific and technical information

Scientific information from research is usually reported in the archive literature of the field as a requirement of a professional character.

The scientific information is expected to be used by others with reference credit but no compensation to the original investigator. Government laboratories urge rapid publication of the results of their researchers. Agencies call on their contractors to publish significant results promptly. In the case of basic research grants, the "page charges" for publication in scientific journals are often an allowable cost item. Industrial laboratories vary in their attitude toward publication. There is an advantage in fostering such professional activities, for the industrial scientist, and for public relations purposes. There is a disadvantage in revealing the course of investigations which indicate marketing goals and, after all, present competitors with useful information free of charge. With both public and private support there is an attempt to gain patent protection for research results of

[85] Schon, Donald A. "The Fear of Innovation," International Science and Technology, November 1966, p. 71, 74.

potential practical value before publication in the scientific literature. In any event the time lag between discovery and publication may be quite long—up to several years.

The Constitution recognizes the need for proprietary protection to gain wide and early benefits from technology. Section 8, Powers Granted to Congress states: "To promote the progress of science and useful arts, by securing, for limited times, to authors and inventors the exclusive right to their respective writings and discoveries." This led to patent and copyright laws with their definitions of originality, state-of-the art, and value. It is not clear whether unpatentable new technology should qualify for a degree of proprietary protection or not.

It might be possible to develop some new protection and reward system for the creators of technology which would stimulate dissemination. Some special treatment is needed for the nonpatentable but valuable devices and techniques which make up a great share of the "improvement" in innovations. J. S. Butz, Jr., of Air Force magazine has suggested a "true" value concept in which a sort of technical judiciary would identify and trace the lineage of significant technological contributions, identify the originator and award an appropriate compensation. This process would occur *after* successful commercialization of new products, processes or services embodying the technology. As an example he discusses the important "coke bottle" shape for aircraft:

> The development and use of the area-rule concept in airplane design serves to illustrate the workings of one possible type of "true" value system. The area rule is ideal for the lineage of its key ideas and has been discussed by many technical authors.
>
> Briefly, it began with the development of a specific mathematical theory which could be used to predict flow conditions on high-speed aircraft. Wallace D. Hayes originated this theory while employed at North American Aviation. No one, Hayes included, was immediately able to see that his equations could be useful in reducing the drag of airplanes flying near the speed of sound. It remained for Richard T. Whitcomb of the National Advisory Committee for Aeronautics' Langley Laboratory to make this deduction and prove it through wind-tunnel tests.
>
> Several aircraft manufacturers put Whitcomb's ideas to work. The most notable was Convair, whose F–102, F–106, and B–58 depended on the area-rule application for success.
>
> Under a "true" value system Convair would have been entitled to compensation for its practical application of the technique and for development and production of the aircraft. In a "true" system both North American and the Langley Laboratory also would have been compensated for the original ideas which were generated within their organizations and which were crucial to the success of the entire multibillion-dollar effort.[86]

b. Patent Policy

The question of Federal patent policy will not be discussed in this report but the eventual outcome of the intensive debate on the subject will be significant to technology transfer. Whether patents resulting from Federal R. & D. sponsorship are exploited via a Government licensing agency or transferred in title more generally to industry, the protection of the invention may be retained. The question is subdivided into the aspects of direct exploitation by the holder or by license. If the Government holds title it will not be likely to develop the patent further with public funds. It may follow an active licensing

[86] Butz, J. S., Jr., "Are Research and Technology Outgrowing Free Enterprise?", Air Force magazine November 1964, p. 44.

program to interest industry in the invention. Licensing can be either nonexclusive or exclusive, and with or without a royalty fee. A nonexclusive royalty-free license from a Government agency is little more than a form of open publication. The developer must establish his competitive position by adding more technology to the invention or by having an existing manufacturing or marketing advantage.

Exclusive licensing as practiced by either Government or industry has the effect of transferring the invention from an organization which is not willing to exploit it to one which will, with a royalty fee as a possible means of paying back some of the costs of R. & D. Some private firms promote the patents they own; others do not.

The promotion of patents held by private nonindustrial organizations such as universities and foundations has been successful. The Research Corporation history is an interesting example. Almost 200 colleges, universities and scientific institutions assign patents to the corporation in return for legal assistance and a share in the profits from future exploitation. A recent article summarizes the system:

Institutional patent services

Through arrangements with Research Corporation the institutions may submit for evaluation such inventions made by their staffs as they wish. In making its evaluation, the patent staff uses as criteria the patentability of the invention, its potential commercial usefulness, the prospect of inducing industry to invest in its development, and other less tangible but substantial reasons for patenting, such as benefit to the public or broad, long-range scientific importance.

If the staff's evaluation is affirmative, the invention is assigned to Research Corporation, which then proceeds to seek patents and license them to industry. The Foundation's specialists work closely with the inventor and outside patent counsel in preparation of patent applications and in following the course of patent prosecution, often becoming involved factually with interferences, appeals, and similar matters that are not exclusively problems of patent law.

After the patent application has been filed, Research Corporation selects qualified industrial firms and discusses with them the invention's technical significance and its potential utility. Since the gap between the laboratory and the marketplace can generally be bridged only by further work on the invention, a major factor in the choice of a potential licensee is the adequacy of its research and development facilities and its willingness to commit the funds for commercial development. As industrial interest is generated, Research Corporation negotiates the appropriate license agreements.

All the costs of evaluating invention disclosures, filing and presecuting patent applications, and licensing are borne by Research Corporation. Certain unusual expenses, such as the cost of patenting in foreign countries and of court litigation in defending the validity of patents, are borne initially by it, but eventually are shared by the institution and the Foundation if royalty income is generated.

Relatively few inventions are likely to have the wide usefulness that results in substantial royalty income; most will produce little, if any. Even when an invention is successful, the receipt of first royalties rarely comes in less than three to five years after the start of commercial development. When royalties on an institutional invention do begin to flow, payments are made to the inventor and his institution in accordance with the institution's patent policy. The inventor's share in most cases is 10 to 15 percent of gross royalty, with 85 to 90 percent being shared equally by his institution and Research Corporation.

Support for grants programs in science

The Foundation's share of this income, including the royalties derived from patents given outright, is devoted to its patent programs and grants programs.[87]

Clark Kerr then President of the University of California wrote to the subcommittee:

Under the University policy regarding patents, inventors are given an opportunity to share net royalty receipts with the University. Thus, investigators are

[87] Marcy, Willard. "The Endowment of Science by Invention." Research Management, vol. 9, November 1966, pp. 377, 378, 379.

given an added incentive to diligently report all possibly patentable ideas for the board's consideration.

When reports of possibly patentable ideas are received, the University's specific patent obligations to sponsors of research, if any, are determined and discharged. Reports of those inventions in which the University has rights are reviewed as to whether or not the ideas are considered patentable and of commercial use. The regents of the University being opposed to protective patents per se, applications for patent are authorized only on those possibly patentable ideas which appear to have commercial value.

On the basis of the University's experience in maintaining a patent program for almost 25 years, it has been found that new technology involving patentable material is more likely to find its way into public use when patents have been obtained and licenses issued under the prevailing patent laws and business practices than would be possible under public patents. Public patents per se do not always serve the best interests of the public, for manufacturers are likely to shy away from such inventions, irrespective of their usefulness, when no periods of exclusivity, within which development costs might be recovered, are possible.

In some industrial cases the Government has forced licensing because of antitrust situations. These and other ramifications of the patent system show that proprietary protection can vary widely as it affects innovation and diffusion of invention.

When technology is not patented or is not patentable, and when it is not disseminated in the scientific literature, it is often treated as a trade secret or proprietary information. The law protects the owners of such technology against its theft and unauthorized dissemination. Employees may not leave a firm and communicate this knowledge to another without permission, even when they have been involved in the original R. & D.

Technology transferred by Federal programs will come under some part of the spectrum of protection. At present it seems to be treated as scientific information, available on a nonexclusive basis. Whether this policy inhibits the willingness of industry to build further on the technology cannot yet be established. The views of agencies and contractors on reporting new technology are discussed on p. 159.

[illegible]

VIII. THE PROCESS OF TECHNOLOGY TRANSFER

A. Technology Transfer Dimensions

A useful three dimensional framework for discussing technology transfer is shown in figure 1. The vertical dimension is the familiar

THREE DIMENSIONAL TECHNOLOGY TRANSFER FRAMEWORK

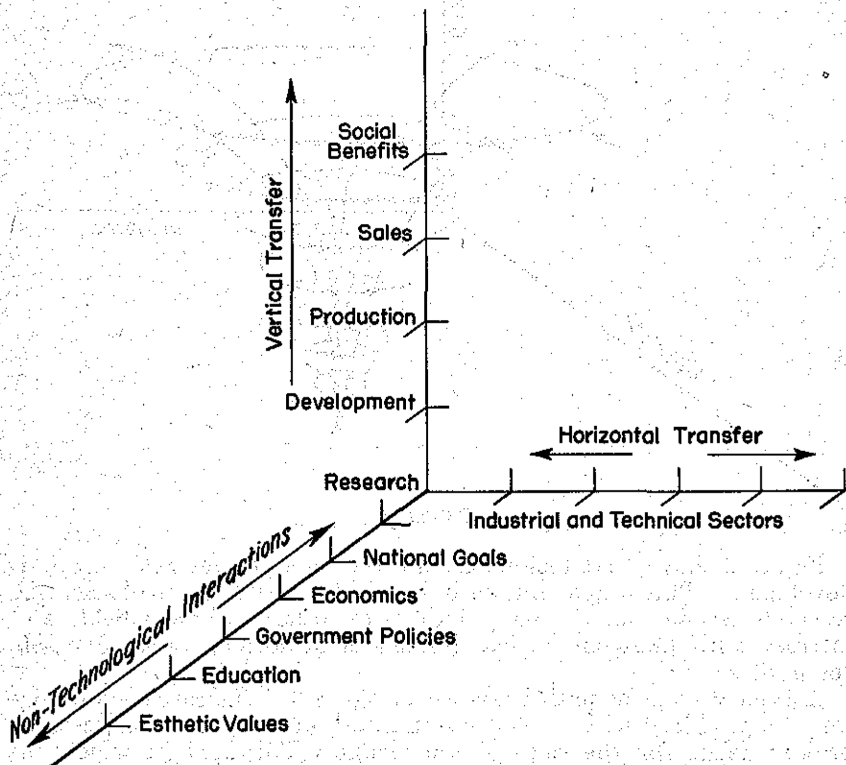

Figure 1

progressive development of scientific ideas and facts into sales and social benefits. Most technology, when transferred at some point in this scheme undergoes further development before introduction into the market. The cases where direct horizontal transfer from one field to another results in a useful end product are rare in the R. & D. stages but may occur frequently when a product is on the market. For the most part horizontal transfer is followed by additional vertical transfer. The third dimension shows the relationship of nontechnological effects on innovation and diffusion.

THE DIFFUSION OF TECHNOLOGY

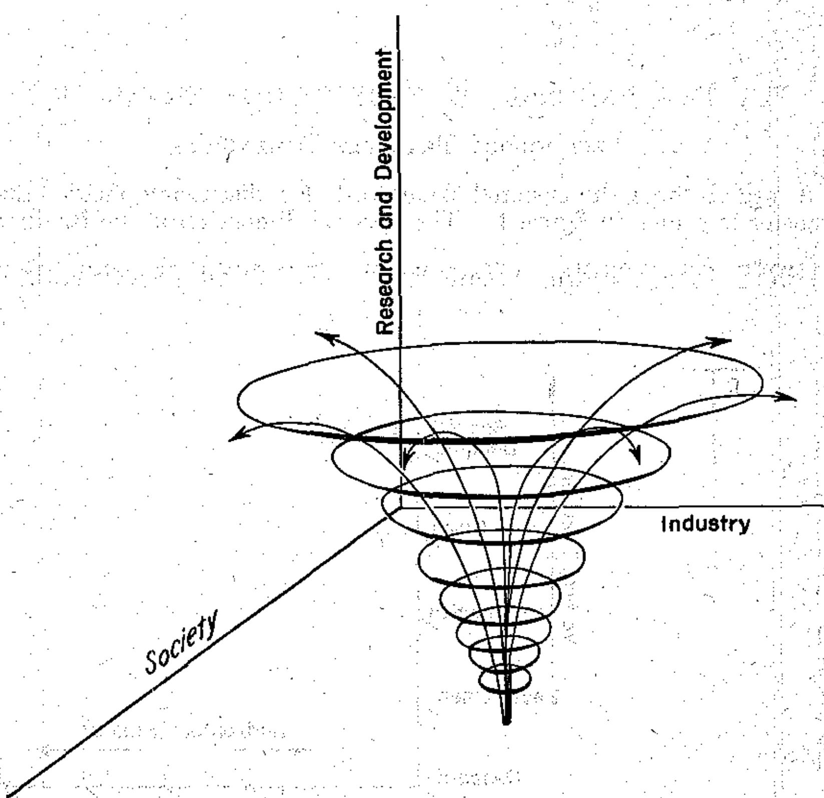

FIGURE 2

Figure 2 shows that technology diffuses to a greater extent as it is developed. This simple illustration indicates how one line of scientific research can impact on many industries, other technical fields and interact with nontechnological influences in society (after Jantsch, see p. 8).

A typical transfer path is shown in figure 3. Research knowledge may be produced with no end use in mind, in terms of basic research or knowledge for the sake of knowledge. The field in which the research originates may find no immediate use for the results but scientists in another area pick it up at point A and develop the idea further, perhaps to the point where a device or technique is invented. In this example it is assumed that further development does not occur in this field but the reduction to practice becomes known to industry, Government or other applied research groups at point B. The invention is introduced into the economy through innovation in several different forms, by adding engineering, testing and evaluation at point C. Financing, marketing, and other nontechnical effects are both felt and made as the technology develops and diffuses at point D.

The total picture of technological change would show thousands of such transfer paths interacting with one another. Time would be

TECHNOLOGY TRANSFER PATHS

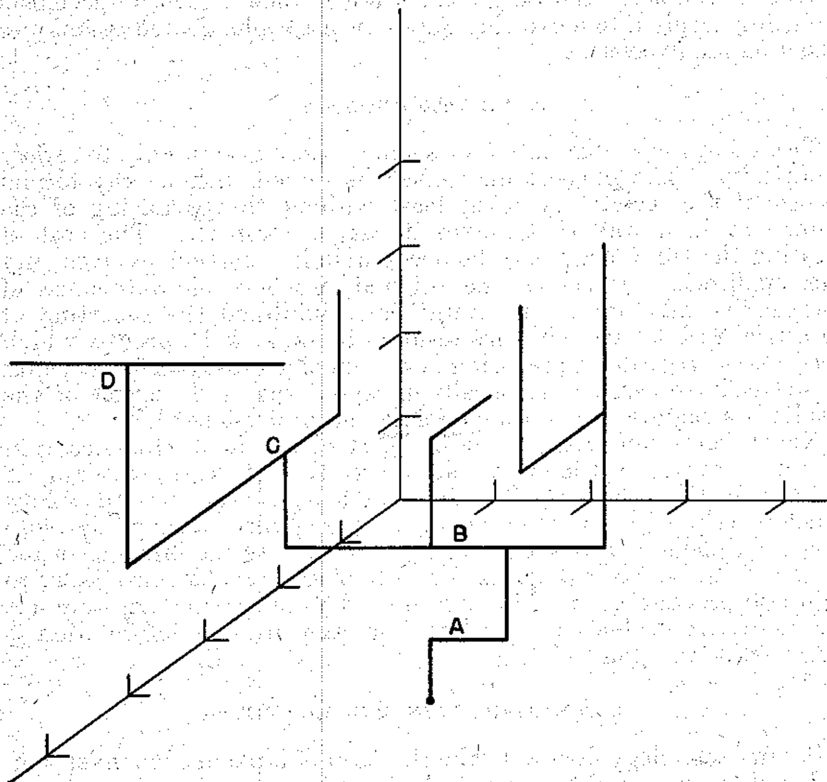

FIGURE 3

present as a fourth dimension, showing some dormant periods and others of rapid advance. The widespread utilization of technology may take many decades. A program in technology transfer would have as one of its main objectives the selective and purposeful speeding up of the diffusion process.

B. Information Processing

1. SCIENCE

Much of the science used by applications researchers and engineering developers is acquired in their formal education. And before it was taught, a timelag occurred during which the facts and relationships were verified and packaged. The explosion of scientific information has revealed the conventional educational process as inadequate. Reeducation and continuing education are necessary for productive scientists and engineers. The concept of multiple successive careers has attracted attention. University instructors are no longer the only teachers as industrial and Government researchers communicate their own findings to the profession. Facts which are old to one field become new raw material for developments in others as technologies involve more different disciplines. In fact, interdisciplinary science is probably the only kind there is today. Even specialists inquiring deeply into narrowing questions use sophisticated techniques based on many sciences.

2. NEW TECHNOLOGY

Technology is accumulated for some purpose even if only to satisfy a curiosity. The purpose may often be served without any formal record of the technology or at least without the packaging of the know-how in a way that makes it easy to transfer. The cost of creating the technology may be acceptable if a portion receives only one application or solves the original problem. Maintenance of competitive advantage has traditionally inhibited the reporting of industrial technology. This has resulted in an R. & D. process which does not clearly call for preparing new technology for transfer; whereas in scientific research it is usually accepted that publication of the results is a requirement for a complete and professional job.

New science can originate in any part of the R. & D. process; in trouble shooting a product which is already being manufactured, or in fundamental research. But the large body of facts and know-how which is technology comes into being during applied research, development, and demonstration engineering. These are the bits and pieces of knowledge which a program for technology transfer must judge to be worth processing for additional use. The processing steps are not free, so some evaluation to select from the mass of information is indicated at the point of origin.

3. IDENTIFICATION AND REPORTING

If new technology does not take the form of a patentable invention, and is of too practical a nature to be included in a scientific report, it may not be identified or recognized beyond the immediate technician or laboratory where it originates. The technology may seem so routine that it is not worth mentioning; or may seem (to the investigator) so specific that it could not be useful elsewhere. The R. & D. personnel may not be those best equipped to identify and report technology which has potential for transfer. Just as R. & D. organizations maintain patent departments to assure the identification of inventions, special training and assignment of personnel may be necessary to find new technology. If a purposeful transfer program is considered then it must operate on the widest possible input and the identification and reporting phase is of primary importance (see p. 122 for NASA procedures). On the other hand the cost of reporting means that trivia must be filtered out even at this early stage of the process.

4. SCREENING AND ORGANIZATION

Any information handling system can be glutted with trivia. Some judgment must be made as to what is an insignificant variation on the routine and what constitutes a meaningful or ingenius technique. Then the bits and pieces must be organized into categories and definitions of a common thesaurus.

5. STORAGE, INVENTORY, AND RETRIEVAL

The technology must be recorded in a systematic fashion in one place (with replicate copies as necessary). A means of knowing what is in the system and of getting information out on the basis of adequate description is essential. The ability to "browse" through available facts is important to the inventor and innovator and should be a feature of any technology transfer system.

6. PUBLICATION AND DISSEMINATION

Some technology will be so obviously useful to the operators of the system that formal publication is warranted. With other knowledge, it is more important to publicize the accessibility of the retrieval system and the kinds of facts which are collected and stored. Another approach to publication is the assembly of related bits of technology into a state-of-the-art review for publication. These costs are appreciable. Good technical judgment based on demands from users can select the areas for emphasis in publication.

Dissemination is related to the traditions of the knowledge industry and the source habits of users. The competition for the reading and searching time of the innovator is so great that he will not expend extra efforts to get information unless its particular value is recognized. It should be noted that all these stages require technical judgment which means that trained personnel must be made available. NASA estimates that one new technology agent should be employed for every 300 researchers. Estimating 500,000 U.S. scientists and engineers as active in R. & D. yields a requirement of about 1,700 workers in identification, reporting, and screening.

C. Sources of Scientific and Technical Information

1. CHOICE BY THE INNOVATOR

The innovator will arrange to obtain the required technology for a business venture in the same way he acquired other ingredients such as financing and labor at least cost in time, money, and effort. Low-cost sources may be suppliers of raw materials or equipment and their technical sales organizations, the trade press, catalogs, meetings, and exhibitions. Greater expense is encountered in professional journals, patents, consultants, formal courses, association memberships, and abstracting services. The most costly technology is acquired by performing specifically directed research either within the firm or by contract to a commercial nor not-for-profit institute. Of course, the adequacy and quality of the technology must balance the cost so that there is no obvious preferred source for a particular information requirement.

The choice of source is apt to be made on the basis of confidence established by training or past experience. Informal communication is much more important than formal as the rank of the communicator increases. High-level decisionmakers depend largely on personal contacts rather than written material.

The Denver Research Institute, in a study for NASA, has surveyed a number of firms in a variety of industries as to their external sources of scientific and technical information. In decreasing order of importance the sources were ranked as follows:

Professional journals
Trade publications
Meetings, conferences, and shows
Supplier personnel
Vendor catalogs
Textbooks and handbooks
University and other consultants
Customer personnel
Government publications
Libraries
Abstract and index services
Formal courses
Patents
Professional and industry associations
Mass media
Formal information dissemination centers
Clipping service
Other channels[88]

2. GOVERNMENT PUBLICATIONS

The relatively low ranking of Government publications and formal information dissemination centers as compared to conventional publications may reflect the confidence factor. The applications engineer is educated to refer to the tested screening and endorsement of professional journals for new technology. Government contract progress reports are notorious for containing preliminary and incomplete information. Other Government publications may not have passed through a rigorous editorial review process. The information centers are recent additions to the list of sources. It appears that one of the tasks of a technology transfer program is to demonstrate an upgraded quality of Government derived information and then acquaint users with evidence of quality.

The Denver Research Institute report concludes:

> Our research indicated that many people in commercial industry involved in technology acquisition do not even think of Government research as offering the possibility of useful information for them. Much less are they convinced that the Government research dissemination channels are worth monitoring or searching. A majority of the respondents in the firms studied assume they will hear of any worthwhile Government contributions to technology through nongovernmental channels, while a substantial minority assume that Government-developed technology is not even pertinent to their work. Therefore, it appears important that there be more Government interaction with all of the educational processes through which commercial industry scientists and engineers acquire their education.
>
> The very skepticism of many commercial industry personnel about the usefulness, to them, of Government-developed technology argues for dissemination through the conventional channels. These are the channels carrying the prestige of the intellectual market place. Government technology passing through the channels' screening and editing is somewhat preselected for their users, and may be more readily accepted because it has survived this competitive process.
>
> * * * * * * *
>
> Professional journals with their board of referees and editors serve a vital purpose in their market-process of judging the utility of scientific and technological publications. It is suggested that Government agencies should explore the possibilities for supporting these activities which seem vital to effective technology transfer.
>
> The clearinghouse for Federal scientific and technical information appears to be the best known source of Government technological publications to our respondents. As such, it would seem to merit support and cooperation from all of the governmental technology generating agencies.
>
> Consistency in technology transfer policy is a problem throughout government. Different agencies have varying policies about making their research results readily available to commercial industry. More uniformity is needed, and it would seem that the growing demands for socially useful research results will encourage agencies to more toward more effective and more user-oriented dissemination.

[88] Denver Research Institute Final Report, NASA Contract No. NSR 06-004-039.

The Federal Government is leading the way toward national systems of technological information. It is suggested that it make maximum use of existing channels of technological communication and of existing resources. It should seek the participation of universities and industry, even if it must coax them, in the design of such systems. It seems particularly important that industries and firms thought of as being less technologically sophisticated be included in such design efforts. Otherwise, overspecialized information systems might be oriented toward particular groupings of firms and might have upsetting effects on existing industry structure and industry concentration relationships. In other words, the experience with mission-oriented, Government-supported information centers may not be wholly applicable to fostering technology transfer in the diverse industry and university sectors.

Our research indicates that commercial industry research, product, and management personnel all spread their technology acquisition efforts over numerous channels. This pattern is not apt to change abruptly. It suggests that new systems be designed for redundant dissemination into various channels, including those now in use.[89]

Sumner Myers, in a report to the National Science Foundation, studied 75 cases of innovation in six industrial firms.[90] It is perhaps significant that most of the information inputs were from outside the company but in the private sector. Where Government funding was a source, the Department of Defense, which has no overt formal transfer program, was the most important agency. The report summarizes:

HIGHLIGHTS

The most typical innovations analyzed in this study—

Were directly activated by technical problems and opportunities rather than market factors.

Were capital goods—items that the firms expected to use in their own production processes.

Were changes that improved performance, increased durability, or cut manufacturing costs of an item.

Usually did not affect productivity of the innovating firms.

Were moderate in scale, costing between $25,000 and $100,000 to implement.

The most typical inputs of information analyzed in this study—

Were generated in the private sector without the financial support of the Government. But when Government funds were involved, the Department of Defense was the major source of support.

Dealt with highly detailed design and performance characteristics of some kind of "hardware."

Came through personal contacts, including vendors and potential suppliers.

Had been acquired by the innovator during the normal course of his professional training or vocational activity.

Were well-diffused and readily available to innovators in the firm's industry.

Were not obviously applicable, requiring either invention or adaptation before being used.

Solved or expedited solution of particular problems that the firm was already working on. But many of the inputs stimulated basic ideas for new items or improvements that the firm had not been thinking about.

3. MANPOWER MOBILITY

The importance of personal contact is stressed by all studies of the transfer process. Much technology is packaged and transported in the form of the researcher himself. This will probably always be the case, regardless of how elaborate a system is set up. Therefore, the mobility of manpower is an important factor in diffusion. Technical personnel change employers frequently in the early stages of their

[89] Ibid.

[90] Myers, Sumner, "Industrial Innovations, Their Characteristics and Their Scientific and Technical Information Bases," National Planning Association, April 1966, p. 2.

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careers. Later on, pension programs, age discrimination, trade secrets laws, and progress into management decrease mobility. This is partially compensated for by increased travel and professional meeting attendance at which ideas and technology are exchanged. Although technology transfer may not be a significant point in setting policies which govern manpower mobility (if indeed a free society is subject to such policies) the converse is important. Whatever trends occur in the interchange of scientists among industries and fields will affect the rate of information diffusion.

4. DEPARTMENT OF DEFENSE EXPERIENCE

The rationale for Government sponsorship of research and development is an illustration of the thesis that demands (recognized needs) are the motivation for the acquisition and organization of new technology. Science and engineering are not considered to be purposes of the Government. A responsibility is felt for public funding of basic research, particularly as it is a part of higher education. But 80 to 90 percent of Federal R. & D. funding is in support of well-defined objectives within approved agency missions. Just as in the purposeful, directed R. & D. of private industry, the application and use of the research results (or vertical transfer) is planned from the start. The "market" definition precedes the acquisition of the technology. John H. Rubel, former Assistant Secretary of Defense, suggests that Government can apply this same technique to public needs other than military or space programs:

> There's no silver bullet, no magic formula, no direct spillover from one field into another, and space technology itself wasn't going to solve urban problems. But one thing we had discovered was that when you create a *market* for rockets to the moon, you get rockets to the moon. There is no market that is not served by some industry or business, and no industry or business that is not served by some market. We'd learned that if you don't have the technology for something, you can create a market and *get* the technology. The method of creating a market for a solution to a problem has proved itself capable of producing the technology to solve the problem.[91]

The Department of Defense has recently analyzed several large weapons projects to see where the technology came from. The review, "Project Hindsight," concludes that innovation is highly correlated with need recognition. In these complex systems, any substantial advancement was necessarily the result of integrating many bits and pieces of technology, often with synergistic, not merely additive effect. It is not surprising that in 85 percent of the successful innovations the technology was acquired after need recognition by the applications engineering group responsible for the system performance. Innovators who did not understand the current and anticipated needs of the project were less likely to produce useful ideas.

Project Hindsight has been interpreted by some observers to indicate that basic research results from Department of Defense programs do not contribute to weapons development. However, the study actually shows that basic research facts take quite a long time to appear in finished systems. For the most part, they must be taken through a directed applied-research stage. The deliberate effort to

[91] Quoted in New Yorker magazine, Aug. 13, 1966, p. 20.

couple innovation to real problems was the motivation for successful development:

That is, science and technology funds deliberately invested and managed for defense purposes have been about one order of magnitude more efficient in producing useful events than the same amount of funds invested without specific concern for defense needs. Thus, we see that although technological "spin off" into defense weapon systems from the nondefense sector exists, it is very small, and it is quite inadequate to produce the number of innovations needed to make possible the large increases in performance which have been attained.

* * * * * * *

There is no question that over a long-time scale undirected research has had great value. The sequence of contributions in atomic and nuclear physics culminating in the discovery of fission in 1939 has had a revolutionary impact on military arms and strategy. Without the organized body of physical science extant in 1930—classical mechanics, quantum mechanics, relativity, thermodynamics, optics, electromagnetic theory and mathematics—only a fraction of the technology events could have occurred. Thus, in the past, in at least these areas, undirected research has paid off on the 30-to-60-year or more time scale. In our study we see no evidence that this situation has changed. However, the fact remains that the contribution from recent (essentially, post 1945) undirected science to the systems we have studied appears to have been small.

We emphasize that this conclusion does not question the value of scientific research. (Recalling fig. 10, 8 percent of the identified events were scientific in nature.) Instead, it focuses on the relative values of alternative practices in the management of scientific research and suggests that the length of time to utilization of scientific findings is decreased when the scientist is working in areas related to the problems of his sponsor.[92]

D. The Costs of Technology Transfer Efforts

If the transfer of accumulated technology is to be the subject of overt Federal programs, some measure of the costs involved is necessary. From the Government standpoint it may be assumed that the dissemination and application phases will eventually be self-sustaining from industrial fees. This assumption does not refer to the continuing programs of aid to small business or regional development. Nor does it refer to the direct primary transfer of technology by the Department of Agriculture, the Department of the Interior, and similar programs which develop broadly applicable data and information.

The identification, reporting and processing for dissemination may become continuing Government costs. A rough estimate is constructed as follows:

Special analysis I of the fiscal year 1968 budget states:

Both the existing science information activities of the Federal agencies designed to put data on research into the hands of users more effectively, and investigations designed to make the entire National effort in this field more efficient, will be strengthened in 1968. Approximately $60 million will be provided for the support of research and development on scientific and technical information systems, techniques, and devices.

Assuming that this figure includes the current NASA and DOC dissemination programs, the direct costs to the Government could be expected to remain $60 to 100 million for a continuing or somewhat expanded program. The indirect costs of the Government arise from increased allowable charges by contractors for the performance of the identification and reporting function. NASA guidelines suggest that one-half to 1 percent of the direct science and engineering labor would be appropriate. Assuming that one-half the total R. & D. expenditure

[92] Sherwin, C. W., and Isenson, R. S., First Interim Report on Project Hindsight (summary), Office of Director, Defense Research and Engineering, Department of Defense, Oct. 13, 1966, pp. 13 and 14.

for direct labor, a $16 billion annual Federal R. & D. budget would represent a $40 to 80 million identification and reporting cost.

These figures, rough as they necessarily are, indicate that a Government-wide technology processing program would require perhaps $150 million annual Federal funding if the dissemination and application costs were supported by fees from users. If this total is accounted as an alternative to direct newly performed R. & D. estimated, for example, as 5 percent of net sales or as a 5-percent royalty, then the $150 million in new technology should result in at least $3 billion in increased sales or public benefits.

This arithmetic exercise shows that while technology originated for one purpose may be considered free for a secondary use, the cost of packaging and transfer is significant. On the other hand, the cost of transferred technology, as an information source for industrial innovation appears to be quite competitive with direct research. Furthermore, the worth of new technology cannot be measured in dollars alone.

Transfer efforts may be manpower limited. The Agricultural Extension Service requires 8,580 man-years annually. The centralized Russian information system (VINITI) is reported to require 2,200 persons just for scanning, evaluating, and translating. Since the transfer agent must be knowledgeable in both industrial practice and information sources, high intelligence and considerable experience are necessary. However, R. & D. scientists and engineers can "double" as transfer agents in many cases if encouraged to do so (see p. 129).

IX. ROLES AND INSTITUTIONS

The opinions and studies analyzed in this report support the proposition that federally derived technology is a valuable resource and that a purposeful transfer program can improve the rate and extent of utilization at a cost competitive with that of directed R. & D. The elements of the transfer process, if not the detailed mechanisms, seem clear. The technology resides in the institutions which make up the Federal R. & D. complex—contractor, university, and government laboratories; agency management groups; and information centers. It is to be used by private industry, large and small, with varying degrees of technical literacy. It is to be transferred by a complex of existing institutions—Federal business services, not-for-profit, and commercial research institutes, consulting engineers, regional, State, and local engineering extension services—and by newly devised transfer operations. The appropriate assignment of roles is extremely important to the success of the concept.

A. The Commercial Utilization Stage

It is necessary to examine briefly the commercial end of the process before further discussing the Government role (or roles).

The introduction of a new product, process, or service into the market and the economy usually results from a risk-profit analysis. This includes judgments on whether the necessary technology is available or whether some sort of scientific "breakthrough" will be required for success. The analysis also considers how well the market can be controlled and protected. This may depend on the source of the technology. A technically integrated firm may prefer to invest in fields in which it already has a strong proprietary position. A technically weak company may be less hesitant to use nonexclusive technology in order to solve problems or enter a new market.

Sales and profits depend on proper market analysis. There is a tendency for marketing personnel to judge innovations by present markets. The entrepreneur is used to being discouraged in this way. Recently a trend toward creative marketing has developed where ingenuity is employed to translate individual and societal objectives into products and services which then generate needs for technology. The "feed forward" of science in stimulating commercial invention is a time honored concept and certainly does operate with significant new ideas such as atomic energy. But the "feed back" of alert sales organizations all the way to the research scientist also occurs. Almost all researchers are interested in suggesting applications for their results, and of considering the possibilities which their new knowledge raises. The stratification and compartmentalization of scientific and engineering activities are overcome to an extent by the very fact that research scientists, and their families do live in the practical world of commercial wants and needs.

The diffusion of technology to other industries and to serve society comes about through the diversity of corporations in the free enterprise system. The social institutions—universities, research foundations, professional societies, etc.—work to spread the utilization of well developed technology. The technical literacy of the whole society is increasing rapidly and this leads to an awareness of the benefits of technological change.

There are exceptions to the "need identification" hypothesis. Some new technology is sufficiently and obviously useful that "solutions do go in search of problems." The problems were already there but not defined in terms of the possible solutions through research and development. Barnes suggests:

> Many research managers insist on "need oriented" research as the way to insure productivity. But in fact, is this type of "practical" research really the most rewarding in terms of improved profit margins? Products like neoprene, nylon, polyethylene, silicones, penicillin, Teflon, transistors, xerography, and the Polaroid Land Camera did not come into being because there was a recognized need for them. The need came after the product was developed.
>
> Most of the products I have just listed proved to be exceptionally good profit earners for their companies. They are the kinds of products most managements really hope for from their research programs. But they are unlikely to come if the research effort is limited to filling existing needs.[93]

The identification of needs may be equaled with serving the future but industry is becoming alert to the opportunity of creating demands and thus shaping the future.

B. Small Business

1. R. & D. REQUIREMENTS

Contrasting with the widely held view that R. & D. is too risky for small business, are statistics which indicate that those small firms which do engage in research are more productive of results than are large companies. Mansfield concludes that increases in the size of firms are correlated with decreasing invention rates (patents per man-year of research effort)[94] Cooper states that R. & D. personnel in small firms tend to be of a higher average caliber, perhaps because less productive researchers will be tolerated in large firms.[95] Accepting these optimistic data for small businesses which do undertake R. & D. is not equivalent to saying that most small businesses should do so. Rather, the statistics are a reflection of the number of small businesses whose primary product is R. & D. results. The fact remains that manufacturing firms must be quite sizable to support any significant amount of R. & D. out of profits. A reasonable lower limit for an integrated research laboratory would be 25 professional scientists or engineers. The annual cost per man including equipment, technician aids, and supplies is about $40,000. This million dollar R. & D. budget would represent 5 percent of $20 million net sales or 3 percent of $33 million. Companies smaller than this may do R. & D. under Government contract which is related to their business but the competition for such funding raises another substantial set of problems.

[93] *Op. cit.*, ref. 84, p. 69.

[94] Mansfield, E., "Industrial Research and Development Expenditures: Determinants, Prospects, and Relation to Size of Firm and Inventive Output," Journal of Political Economy, August 1964, pp. 334–336.

[95] Cooper, A. C., "R. & D. Is More Efficient in Small Companies," Harvard Business Review, May–June 1964, p. 78.

In September of 1957, President Eisenhower called together representatives of large and small business, the R. & D. institutes, and commercial firms and appropriate Government agencies for a President's Conference on Technical and Distribution Research for the Benefit of Small Business.[96] The Conference participants concluded that R. & D., like some form of mass production, could not be scaled down below certain minimum limits. The hazards for small companies investing their own funds in internal R. & D. projects seemed to outweigh the possible benefits in most cases. At the same time, small business was seen to have a definite need for scientific and technical information just as does big business. In summing up the Conference, Chairman Charles N. Kimball said of the small businessman, "Perhaps what he really needs presently is not research and development, but the results of research and development." [97]

2. THE SMALL BUSINESS ADMINISTRATION

The need is clear for aid to firms which are not technically staffed in order to identify technology needs and apply acquired facts. This aid can be provided by grantees of the Office of State Technical Services which are partially supported by Federal funds. Or the "middle ground" research institutes and consultants can give assistance supported by fees or subsidized by government transfer programs.

An alternative approach is the historical role of the Small Business Administration whereby Government employees are trained to assist businessmen at no expense to the private firm. SBA has sponsored several activities in the past which have to do with Federal R. & D. programs. Aid in obtaining R. & D. contracts has been furnished to small businesses.[98]

A Presidential Conference was held on the need for R. & D. in these firms. (See above.) In 1965 the agency sponsored a pilot program with Bjorksten Research Laboratories, Inc., to collect information on plastics from Federal R. & D. reports and to disseminate the processed technology to small business by mailing. SBA is currently working cooperatively with both NASA and AEC technology transfer projects. Another approach is the identification of common technical problems by trade associations with subsequent SBA searches for applicable technology and eventual counseling in application.

These direct transfer efforts by a Government agency depend on the quality and training of the personnel making the contacts. The program is similar to the industrial liaison offices in Great Britain. (See p. 42.) Transfer techniques can be learned although effective transfer agents are likely to have natural entrepreneurial inclinations which are inconsistent with bureaucracy.

Administrator Bernard L. Boutin has informed the subcommittee of additional plans and ideas for SBA participation in technology transfer:

> What we in the Small Business Administration envisage, however, is the adoption of a "Project Foresight," which would require research and development (R. & D.) contractors to expand their final R. & D. reports, in execution of their

[96] Proceedings of the Conference are available from the Clearinghouse for Federal Scientific and Technical Information, as PB 131-460.
[97] Ibid., p. 276.
[98] "Small Business and Government Research and Development," Small Business Administration, Washington, D.C., 1962.

contracts, beyond the immediate mission, and to explore possible commercial uses for the development described in their final R. & D. reports. We would propose, then, that these future refined findings be widely disseminated to specific industry segments within the small business community. With the knowledge thus provided, concerns interested in the utilization of this technology would be enabled to decide for themselves whether or not to proceed to the commercial exploitation of the technical know-how thus made available.

SBA realizes that here, in the utilization process, funds may become necessary, and these SBA stands ready to provide. In fact, on October 26, 1966, a directive went out to all SBA offices throughout the Nation to engage in an "aggressive effort to seek out and assist any small manufacturing firm having both well-qualified management and innovative ideas for new products, processes or techniques," and to process loan applications for these firms in order to finance their innovations. This program is in effect, and actively in operation. Thus, SBA is already promoting technological utilization.

These suggestions, of Government-sponsored development beyond immediate mission requirements, and provision of venture capital are worth considerable discussion. For other SBA comments, see pages 152 and 156.

C. Management of Innovation

1. THE ENVIRONMENT

The need for understanding the opportunities and possibilities in new technology by the nontechnical decisionmakers in business and society can be the subject of governmental efforts. The recent Department of Commerce report on technological innovation states:

The large company is a complex social organization. The fast reaction time we discussed in reference to the small company environment is not easily attainable here. The distance from the chief executive's office to the maintenance shop may be a long way. He is, in fact, often removed from the operational details of his company; surely, he is not familiar in detail with each new venture early in its life time. The complexity of the organization itself leads to certain problems.

There are the "know-it-alls." They explain that they have thought about similar new ideas many times before, and have concluded that there are many, many reasons why each new concept cannot succeed. Or, it will not work because it has never been done before. There are many other reasons why, in this experimental appraisal stage, prior experiences and predispositions rise up to block innovation. Often these take the form of an overly conservative estimate of risk versus probable cost for new ventures. It is easy to make such decisions because there is always the choice of extending the present business rather than taking the organization into unknown territory. As we have noted, the beginning small business has no analogous option.

These are different kinds of problems from those we discussed in reference to the small company environment. There, when the problem was to obtain initial financing for the incipient firm, the problems were largely external ("Can we get the capital?"). Here, we are concerned with what may be a lack of entrepreneurial spirit and commitment within a well-established, well-financed organization. In a complex organization the overriding problem often is maintaining an adequate commitment to a new idea in the face of internal obstacles to change. There is an understandable reluctance to depart from what has been a successful pattern of business. So we come back again to the need for understanding, within and outside the company, of the special problems of managing and exploiting technological change. These problems are no less formidable in a large organization than they are in a small firm. They are just different.[99]

The report recommends:

Recommendation 17

(a) A White House conference on "Understanding and Improving the Environment for Technological Innovation."

[99] Op. cit., ref. 65, pp. 27, 28.

(b) Soon thereafter, a series of regional innovation conferences, composed of governors, mayors, bankers, academicians, scientists, engineers, entrepreneurs, and others—aimed at removing barriers to the development of new technological enterprises, jobs, and community prosperity in the respective regions.

Summing up, we find that the concepts, uncertainties, and other realities of technological innovation are like a foreign language, indeed a strange world, to too many of us. Because of this, we believe the most important initial task before us is to become more widely acquainted with the "language" and "world" of innovation.

Understanding, as Alexander Pope might have put it, is the key to a drawer wherein lie other keys. When we come to appreciate and understand the problems and the opportunities associated with innovation, we can more effectively act on programs that will best encourage beneficial change and the continued renewal of our society.[100]

2. REGIONAL DEVELOPMENT

Regional development is the motivation for State and local governments to participate in technology transfer programs. The experience to date suggests that the first step is elementary education in the opportunities offered by new technology.

The first annual report of the Office of State Technical Services (fiscal year 1966) lists the following major State problems as expressed in the 5-year plans submitted to the agency by local groups.[101]

A. Existing local industries fail to apply full modern methods:
   1. Lack of information about modern technology.
   2. Lack of know-how in applying technological information.
   3. Services needed in support of service-oriented industry.
   4. Resistance to change by some businessmen.
   5. Obsolete equipment and physical plant.

B. Shortage of experienced managers and qualified technical personnel:
   1. Few academic, governmental and industrial research facilities in State.
   2. Young people leaving State after completing education.
   3. Lack of continuing educational facilities to up-date graduate engineers.
   4. Spirit of entrepreneurship often lacking.

C. Economy in transition unfavorably influencing growth and development:
   1. Need for new industry and greater industrial diversification.
   2. Declining agriculture has placed burden of employment upon growth.
   3. Cyclical swings in manufacturing.
   4. Technological changes reducing employment in major industries.
   5. Pockets of poverty in some areas of State.
   6. Problems of urbanization.

D. Location, resource, and climate factors seen as limiting development:
   1. Major dependence on a few resource-based industries with high seasonal fluctuations in employment, for example, agriculture, lumber, construction, tourist trade and mining.
   2. Natural resources and partially processed products being shipped to other states to be transformed into consumer goods.
   3. Physical conditions in State impede industrialization.
   4. Sparsity of population and distance from major markets, resulting in unfavorable freight-rates as a share of cost of both imported and exported materials and goods.

D. Independent Not-for-Profit Research Institutes

At the beginning of the 20th century, the concept of undertaking scientific research and development directed to the solution of specific industrial problems was just gaining acceptance. Up to that time, science had been pursued for its own sake and technological change occurred without any deep understanding or by using whatever facts

[100] Ibid., p. 57.

[101] Office of State Technical Services, First Annual Report, Department of Commerce, Washington, D.C., January 17, 1967, p. 5.

were already available. Prof. Robert Kennedy Duncan at the University of Kansas wrote extensively on applied research and engineering. The Mellon brothers in Pittsburgh became interested in his ideas with the result that he came to the University of Pittsburgh in 1913 and eventually founded Mellon Institute in 1927. Other similar organizations arose—Battelle Memorial Institute at Columbus, Ohio, in 1929, and Armour Research Foundation (now renamed the Illinois Institute of Technology Research Institute) at Chicago in 1936. After World War II, the benefits of applied research had been dramatically demonstrated. The agglomeration of science resources around existing university centers of excellence on both coasts left many regions ill-equipped to introduce new technology and R. & D. methods to local industry.

Farsighted businessmen and civic leaders in a number of cities organized to provide nuclei for regional technology transfer. Table 6 lists the major institutes today. The institutes were chartered to serve nearby industry as contract research laboratories and consultants in employing science for economic growth. Some institutes are loosely attached to universities but most have completely independent staffs and facilities. Original financing varied from personal philanthropy to public subscription to State and local government grants. The not-for-profit label indicates that their public service nature has been recognized by the Internal Revenue Service as exempting their income from taxation. This ruling is contested by commercial R. & D. and testing laboratories who claim that the independent institutes perform identical services in competition with taxpaying organizations. The institutes do, of course, make a profit and collect fees on Government contracts. But the excess of income over expenditures is not distributed to any stockholders or owners; it is plowed back into facilities or internally supported research in the public interest. A few institutes have set up taxpaying subsidiaries for specific commercial activities.

TABLE 6.—*Independent not-for-profit research institutes*

Institute	Location	Founded	Professional staff, 1965	R. & D. dollar-volume, 1965 (millions)
Battelle Memorial Institute	Columbus, Ohio	1929	2,600	83.0
Cornell Aeronautical Laboratory	Buffalo, N.Y.	1946	570	23.3
Franklin Institute	Philadelphia, Pa.	1946	225	5.6
Gulf South Research Institute	Baton Rouge, La.	1965	12	.3
IIT Research Institute	Chicago, Ill.	1936	900	25.5
Mellon Institute	Pittsburgh, Pa.	1927	570	22.3
Midwest Research Institute	Kansas City, Mo.	1944	238	4.9
North Star Research and Development Institute.	Minneapolis, Minn.	1963	25	.4
Research Triangle Institute	Durham, N.C.	1959	171	3.8
Southern Research Institute	Birmingham, Ala.	1945	217	4.8
Southwest Research Institute	San Antonio, Tex.	1947	280	9.9
Spindletop Research	Lexington, Ky.	1961	49	1.2
Stanford Research Institute	Menlo Park, Calif.	1946	1,407	50.0
University City Science Research Institute.	Philadelphia, Pa.	1954	5	.1

The original mission of the independent not-for-profit research institutes was to do exactly what recent studies of technology transfer have found necessary: That is to identify technological needs within firms which are not fully integrated with complete research and engineering staffs of their own. The institutes were to act as transfer agents, knowledgeable about sources of technology on the one hand and able to perceive application possibilities in local industry. Their primary radius of operation was within a few hundred miles of their location.

The concept required considerable education of industry as to the opportunities in industrial R. & D. The major contribution of the institutes was in raising the level of awareness and technical literacy in their regions. They attracted to their staffs (and subsequently trained) a problem-solving type of scientist or engineer—who became what amounted to an institutionalized entrepreneur. This unique public service was developing with considerable success and very little support from Federal agencies during the late 1940's.

Federal Government programs began to support applied R. & D. in rapidly mounting volume in about 1953. (The total for 1953 was $3.1 billion, up from $1.8 billion in 1952, which was the first year since World War II that the 1945 maximum of $1.6 billion had been equalled.) The independent research institutes were a readymade performer for these Federal projects and the large increments of funding were much easier to obtain than the many small industrial contracts. Further, the public service charters of the institutes and their tax-exempt status made it very difficult to turn away Government proposal requests. In a few years, the institutes had been diverted from the regional technology transfer programs. The percentage of their annual contract support provided by Federal agencies changed from 20 to 30 percent to 70 to 80 percent. The institutes became highly dependent on Government R. & D. contract procedures, tailoring their facilities, staffs, and management accordingly.

A case can be made that in serving the Federal Government, the institutes and their regions have been thwarted in proceeding with technology transfer. But perhaps more importantly, they are now better equipped to take part in upcoming transfer efforts. The original concept of "knowing the territory" is still valid, and now the institutes are well acquainted with the sources of technology within the Federal program. The institutes have much closer relationships to industry than do many universities. Their staffs are fully oriented to applied research.

The State Technical Services Act was clearly designed to involve universities although research institutes have been helpful in formulating State plans and may take on specific grant activities in the future. The NASA technology utilization program started with Midwest Research Institute in Kansas City as its first regional dissemination center, but since then has become more involved with universities.

The MRI program, although labeled an experiment, has proved that the institute concept of technology transfer is efficient and workable. Called ASTRA (applied space technology-regional advancement) the program began in 1962. As described in a recent report:

> The ASTRA services fall into three major categories—consultation, information services, and seminar participation. The program is designed around a concept of personalized service.
>
> To be effective in working with client firms, the ASTRA technical professional must have a thorough knowledge of the client's technical needs and interests.

Each client firm is visited twice each year to appraise—and reappraise—the client's needs. In addition, the staff of the client firm is encouraged to visit Midwest Research Institute for consultation with the ASTRA/MRI staff.

Industry response to both, the surveys and the seminars, has been excellent, suggesting that they represent a very effective and efficient means of dissemination.

One of the difficult, challenging, and frustrating aspects of an information dissemination program like ASTRA is to measure accurately its impact on the participating firms. If the information provided is off target and not useful, the firm usually doesn't take the time to report back. If the information provided leads directly to a really significant advance for the firm, industrial secrecy is usually imposed to protect a competitive advantage. The result is that meaningful feedback from the firms is not spontaneously supplied; it must be dug out.[102]

The research institutes would seem to be a focal point for national technology transfer efforts. They are ideal training centers for transfer agents. They are located in regions which have demonstrated initiative in recognizing technological needs. They are a type of institution which is oriented to public service and independent from (but thoroughly conversant with) either government or industry. Technology transfer is their raison d'etre.

The initial financing of a future national technology transfer program will be largely by the Federal Government. A suggestion has been made that the heavy dependence for R. & D. performance by the Government on organizations such as the independent research institutes has engendered a responsibility for sustaining financial support so that other local services may be adequately continued.

Were Government now to recognize the need for building a long-term service capability in organizations with unique or special talents, it would seem an easy matter for Federal agencies to begin to apply to the private agencies on whose services they depend the same principles now applied to the universities. For example, sustaining grants to such organizations could provide funds for administrative costs not allocable to contracts. Such grants could also provide "venture capital" for programs which, though not of current interest to the Government, would develop the general competence of these organizations, and hence their longer-range usefulness to Government.

* * * * * * *

Nonetheless, the real issue is beginning to emerge clearly. Is the nongovernmental organization of the future to be simply an auxiliary to the state, a kind of willing but not very resourceful handmaiden? Or is it to be a strong, independent adjunct that provides government with a type of capability it cannot provide for itself?

If it is to be the latter, and for most Americans the question is one that is likely to admit of no other answer, then we must face up to the difficult problem of how we are to finance these organizations. More can be done on the private side, as private responsibility will—and should—continue. For example, there might perhaps be some advantages to be found in experimenting more widely with the notion of cooperative fund raising which has worked so well for some community chest organizations. But the question must also be raised as to whether responsibility for the general financial health of at least the most important of the nongovernmental organizations should not now be shared by the Federal Government. Certainly the time has come for a comprehensive and careful study of the problem from both the governmental and nongovernmental sides.[103]

The not-for-profit institutes are in a position to impart high leverage to regional technology transfer programs. Whether by sustaining grants to allow the expansion of services not supported by revenues, or by direct contract for performance of Federal transfer activities, these unique organizations will be a vital part of future efforts.

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[102] Alcott, James, "Technology Transfer Via a Research Institute." Research/Development, September 1966, pp. 23–24.

[103] Pifer, Alan, "The Non-Governmental Organization at Bay," the Annual Report of the Carnegie Foundation, 1966, pp. 10, 14.

E. The Universities

Science and engineering are important and often dominant functions in institutions of higher learning. The emphasis is on teaching and research however, and not on technology transfer in a short term sense to business. In the long run, the universities are increasing the technical literacy of the entire society and this will contribute to the demand for, and understanding of, technological change.

Proponents of placing transfer programs in universities have noted that two purposes might be served. First, the professional teaching staff is a source of transfer agents who should be able to educate users as to the value of new technology and assist in problem identification. Second, the exposure of academicians to practical commercial technological needs would result in teaching which produced graduates better tuned to industrial requirements. In addition, the university today is becoming a multipurpose institution of public service closely integrated with the community rather than an ivory tower of knowledge.

The merit of these arguments depends to a great extent on the attitudes of particular university managements. To attract the endeavors of competent faculty members, technology transfer programs must offer rewards and recognition equivalent to teaching and research. The agricultural extension services in land-grant colleges were usually staffed apart from the teaching faculty. Many university research centers are also separated organizationally. It may be difficult to arrange a recognition system for the relatively new concept of technology transfer which will truly involve the faculty and not result in a mere administrative attachment of a dissemination center to the university. Dr. Alvin Weinberg has noted that whereas society is mission oriented, universities are discipline oriented.

The preference of students to pursue pure science has raised concern in industry and government. Dr. Edward Teller states:

> In our educational institutions applied science may almost be described as "no man's land." Recently I interviewed 24 most promising students from the various departments of the Massachusetts Institute of Technology. These departments included mathematics, physics, chemistry, and many branches of engineering. The purpose of the interview was to select students for fellowships in applied science. The interviews revealed that 22 out of the 24 showed a marked preference for pure science. In noting this ratio, one should consider that the Massachusetts Institute of Technology is supposed to have a particularly close connection with technology.[104]

The subcommittee contacted the University of California, the University of Chicago, and the Massachusetts Institute of Technology, three major contractors for Federal R. & D. These institutions called attention to the fact that their faculties engaged in a number of different technology transfer activities apart from the teaching role. Included are consulting arrangements with industry, R. & D. clinics and seminars for business, and participation in "spin-off" companies derived from research projects at the university. Other comments from the schools are found on pages 166–167.

The role of universities in transferring Federal technology to business could be extensive, but specific administrative adjustments will be necessary to get the full benefit of these institutions.

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[104] "Basic Research and National Goals," National Academy of Sciences, March 1965, Washington, D.C., p. 260.

F. Federal Contract Research Centers

These laboratories are operated by various institutions and industries under contract with agencies. They could be given an expanded role as regional technology transfer centers. The value of the contract research centers as a national asset far beyond the performance of their primary mission has been recognized. As agency assignments change and new public needs arise, the centers should be flexible enough to take on new tasks. As an example, Oak Ridge National Laboratory has assisted in studies of a combined nuclear electric power desalting plant with the Office of Saline Water.

Participation of the Federal laboratories in cooperative education projects with universities would strengthen applied research training. On a case-by-case basis perhaps, technology transfer activities could be added to such an arrangement. As with other institutions, the advantage to be gained is a closer coupling of originators of technology with users. The AEC Offices of Industrial Cooperation at Argonne and Oak Ridge National Laboratories are the beginning operations of what could become comprehensive transfer centers. (See p. 130).

A list of the contract centers is presented, adapted from NSF–66–25, Federal Funds for Research, Development, and Other Scientific Activities, fiscal years 1965, 1966, and 1967, volume XV, pages 71, 72.

Federal Contract Research Centers

Department of Defense:
- Secretary of Defense:
  - Managed by other nonprofit institutions:
    - Hudson Institute.
    - Institute for Defense Analyses.
- Department of the Army:
  - Managed by profit organizations:
    - Rocket and Propellant Laboratory (Rohm & Haas, Inc.).
    - Thiokol project (Thiokol Chemical Corp.).
  - Managed by educational institutions:
    - Army Mathematics Center (University of Wisconsin).
    - Human Resources Research Office (George Washington University)
    - Special Operations Research Office (American University).
  - Managed by other nonprofit institutions:
    - Research Analysis Corp.:
- Department of the Navy:
  - Managed by profit organizations:
    - Ordnance Aerophysics Laboratory (Convair Division, General Dynamics Corp.).
  - Managed by educational institutions:
    - Applied Physics Laboratory (John Hopkins University).
    - Applied Physics Laboratory (University of Washington).
    - Arctic Research Laboratory (University of Alaska).
    - Hudson Laboratory (Columbia University).
    - Navy Biological Laboratory (University of California).
    - Ordnance Research Laboratory (Pennsylvania State University).
  - Managed by other nonprofit institutions:
    - Center for Naval Analyses (Franklin Institute).
- Department of the Air Force:
  - Managed by profit organizations:
    - Nuclear Aerospace Research Facility (Convair Division, General Dynamics Corp.).
    - International telephone and telegraph communications systems (International Telephone & Telegraph Corp.)

Department of Defense—Continued
Department of the Air Force—Continued
Managed by educational institutions:
Lincoln Laboratory (Massachusetts Institute of Technology).
Managed by other nonprofit institutions:
Aerospace Corp.
Anser (Analytic Services, Inc.).
MITRE Corp.
RAND Corp.
Atomic Energy Commission:
Managed by profit organizations:
Bettis Atomic Power Laboratory (Westinghouse Electric Corp.).
Engineering test reactor, National Reactor Testing Station (Phillips Petroleum Co. and Idaho Nuclear Corp.).
Knolls Atomic Power Laboratory (General Electric Co.).
Savannah River Laboratory (E. I. duPont de Nemours & Co., Inc.).
Mound Laboratory (Monsanto Chemical Co.).
Oak Ridge National Laboratory (Union Carbide Nuclear Co.).
Sandia Laboratory (Sandia Corp.).
Managed by educational institutions:
Ames Laboratory (Iowa State University of Science and Technology).
Argonne National Laboratory (University of Chicago and Argonne Universities Association).
Cambridge Electron Accelerator (Harvard University and Massachusetts Institute of Technology).
Lawrence Radiation Laboratory (including the Livermore Radiation Laboratory, University of California).
Los Alamos Scientific Laboratory (University of California).
Princeton-Pennsylvania Proton Accelerator (Princeton University and University of Pennsylvania).
Princeton Stellerator (Princeton University).
Stanford Linear Accelerator Laboratory (Stanford University).
Managed by other nonprofit institutions:
Brookhaven National Laboratory[104a] (Associated Universities, Inc.).
Oak Ridge Institute of Nuclear Studies[104a] (Oak Ridge Associated Universities).
Pacific Northwest Laboratory (Battelle Memorial Institute).
National Aeronautics and Space Administration:
Managed by educational institutions:
Jet Propulsion Laboratory (California Institute of Technology).
National Science Foundation:
Managed by other nonprofit institutions:
Kitt Peak National Observatory (Association of Universities for Research in Astronomy, Inc.).
National Radio Astronomy Observatory (Associated Universities, Inc.).
National Center for Atmospheric Research (University Corp. for Atmospheric Research).
Cerro Tololo Inter-American Observatory (Association of Universities for Research in Astronomy, Inc.).

G. The Federal Government

1. THE SPECTRUM OF POSSIBILITIES

Lesher and Howick present the possibilities for the Federal Government in the question:

Should the responsibility of the Federal Government end with:

Publication, i.e., making the results of research and development available (as in libraries, depositories, and journals) for interested parties, but placing the full burden of discovery and use on the potential user?

Bibliographic control, i.e., making it easy for the interested parties to seek out relevant publications?

[104a] Operated by nonprofit corporations sponsored by educational institutions, but not directly managed by them.

Dissemination, i.e., actively delivering relevant publications to interested parties?

Communication, which implies some personal (versus only paper) involvement in defining the needs and objectives of the user and seeking to match specific technical information to those needs, so that understanding is achieved?

Education, which implies not only communicating specific information but also building the background of the recipient of the information to a level where the relevant information can be more effectively utilized?

Encouragement, i.e., actual continuing consultation with the user of the information to promote utilization (versus transfer, per se) of the technology?

Assistance, i.e., Government aid in adapting technology generated for a Government mission to make it useful for nongovernmental purposes (or one Government agency adapting its technology for the use of another Government agency)?

Development assistance, which implies Government action to add to the knowledge base and develop new technology specifically to meet needs and objectives in the civilian economy? [105]

These activities can be added to the identification and processing steps (see p. 67) to complete the initial stages of technological change.

Rosenbloom, in his study for the National Planning Association comments on the responsibilities of the Federal Government, industry, and a "third force" of universities and the research institutes; the knowledge transformation industry:

Although the existence of some Federal responsibility in this area seems beyond doubt, there is a serious question of degree. The substantial involvement of the Federal agencies in modern science and technology implies some responsibility for the consequences of that role. Since two-thirds of all R. & D. work is supported by Federal funds, the Government clearly has a responsibility to make the results of this work available for the widest possible use. The establishment of a Federal clearinghouse to distribute all technical documents resulting from Government research and development moves in this direction.

An important question remains unanswered. How far should the Government go, not only in making findings available, but also in selecting and tailoring reports for most effective use by private enterprise and even in promoting the receptivity of private enterprise for utilizing the advanced technology? Here the question of what is proper activity for the Federal Government merges with the question of what means are available to the Federal Government to act effectively without interfering with the responsibilities of private enterprise.

Whatever the limits of Government efforts to facilitate transfer, it seems clear that coordinate activity on the part of private industry will be a prerequisite to the success of the Federal effort. Defining the responsibility of the private firm in this regard, however, is more difficult. We presume that the private enterprise best serves the general welfare by the pursuit of its own interests (within the bounds of law and custom). The ultimate payoff and best test of the transfer process is the corporation's willingness and capacity to effect innovation. In the private corporation, however, special mechanisms, instituted to facilitate the acquisition of new technology, clearly must pay their own way in the long run. There is a cost of receptivity to new technology and if that cost outweighs the benefits derived by the firm, one cannot expect continuation of such programs. Unfortunately, the costs are likely to be far more tangible than the benefits, suggesting that profitable programs may be forgone or abandoned because of the difficulties of making an accurate evaluation.

The educational and research institutions also have an important role in the transfer process. Research and training in the new "sophisticated" technologies and their incorporation in the heart of educational programs will lead to wider understanding and acceptance, and ultimately to their commonplace application. Without discussing the complex issues concerning the nature and extent of university responsibilities, their dual relevance to this subject should be noted. The university influences the utilization of technology both through the quality and character of the training it gives to technologists and through its own activities generating new technology. The Government, in turn, by its actions may help or hinder the educational and research organizations in fulfilling their functions.

A middle ground institution, probably in the form of some kind of specialized information center, might help to couple sources and users of technology. It

[105] *Op. cit.,* ref. 77, p. 48–49.

would have to be familiar, on the one hand, with the characteristics of the available national information resources and, on the other hand, with the conditions within the firms which are to be service. Such a center could also perhaps assume much of the responsibility for the creative transformation of the information which is likely to be so necessary to effective innovation. The center should be in a position also to answer specific questions in relation to problems already perceived by private enterprise. Werner Hirsch, of the University of California, has referred to these activities as an emergent "knowledge transformation industry."

Even though the initial stages of such a knowledge transformation industry can already by observed, it is not yet clear what structure would be most appropriate for this "industry" or what its chances of success are in the long run. We take note of the possible role of such a "third party," not as an argument for the encouragement of new institutions but as a recognition that several such organizations have already emerged.

Despite the possible contribution of Federal programs and third parties, the ultimate responsibility for transfer rests with the business firm. Whatever the effectiveness with which these new functions are performed by Federal agencies, or by intermediaries—and there is evidence of modest progress in these directions—the greatest benefits will be derived by the firms which are themselves best equipped to acquire, appraise, and implement new technical information. The most significant problem here would seem to be the achievement of an effective coupling across the boundary enclosing the corporation itself. To do this requires both sensitivity on the part of the Federal agencies to the mechanisms by which businesses may fruitfully equip themselves to acquire and use information, and awarness on the part of business of the steps being taken by external agencies.[106]

The Federal responsibilities for technological innovation are defined by the Department of Commerce Panel on Invention and Innovation to include "studies of the innovation process, the adverse impact of Government contracting on small technologically based firms and the absence of an effective Federal spokesman for such firms.[107] The report recommends:

RECOMMENDATION 9

The Department of Commerce should broaden and complement its studies of the innovative and entrepreneurial processes by initiating an integrated program, in cooperation with the universities, including the preparation of empirical data and case materials on these processes; studies of the venture capital system; and experimentation with teaching methods to develop innovative and entrepreneurial talents.

RECOMMENDATION 10

An interdepartmental ad hoc review of current contracting policies and procedures of such agencies as the Department of Defense, the National Aeronautics and Space Administration, the Atomic Energy Commission, and the National Institites of Health, to insure that these policies are conducive to the long-range growth of small enterprises.

RECOMMENDATION 11

The Department of Commerce should serve as the Federal spokesman representing the interests of new technologically based enterprises and should develop the necessary competence and organization to deal effectively with problems associated with venture capital availability and the generation of such enterprises.[108]

A recent study by the Rand Corp. and the Brookings Institution suggests the establishment of a National Institute of Technology for experimental development of advanced technology under Government sponsorship.

[106] Rosenbloom, Richard S., "Technology Transfer—Process and Policy," National Planning Association Special Report No. 62, July 1965, pp. 29, 30, 31, 32.
[107] Op. cit., reference 65, p. 45.
[108] Ibid., pp. 45, 46, 47.

FUNCTIONS AND CHARACTERISTICS OF THE INSTITUTE

There are two possible models for such a program. One would be to follow the example of the National Advisory Committee on Aeronautics and conduct the research in Government facilities. The second would be to follow the example of the National Science Foundation and work principally through support to outside organizations. (The National Institutes of Health and the Department of Agriculture research support programs are somewhere in between.) Greater flexibility suggests the second approach, though the organization will need some in-house capability to evaluate proposals. One possibility would be to link the Institute with the National Bureau of Standards. The balance between in-house research and grants can be worked out as experience accumulates, but the Institute would probably be primarily a grant-giving agency. It should be willing to take the initiative to point out promising areas to which it would give priority.

To stress the analogy to the National Science Foundation and to the National Institutes of Health the proposal is called a National Institute of Technology. The mission of this organization is to support research and experimental development meeting three criteria:

1. The proposed research or experimentation, if successful, would produce knowledge which could be exploited to yield significant increases in the performance or efficiency of a class of products or processes.
2. There should be a reasonable chance of success at a level of funding commensurate with a high rate of return, if successful.
3. It should be established why business firms presently are not undertaking projects of this kind despite the high expected social rate of return.

There are some extremely difficult questions regarding whether the Institute should aim principally to support work done by business firms and private inventors, or work in the universities. It is quite possible that the former would yield the greatest payoffs—that the Institute should aim to stimulate proposals from imaginative engineers in business firms, and to provide encouragement and financial assistance to freelancers. There would, however, be serious problems regarding dispositions of any resulting patents. Business firms or private inventors would probably not accept Government support for ideas they thought exciting if the price of such support was abandonment of patent rights, and while the useful knowledge created usually would transcend the patent rights, a privately held patent might obstruct others from capitalizing on the knowledge created.

While some kind of a patent licensing arrangement could be worked out, it is suggested that the objective of the grants should be viewed as knowledge for general use in the public domain. Any resulting patents should vest with the public, and there should be full publication and publicity of results. This would mean that the bulk of the grants would go to colleges and universities (principally engineering departments) and nonprofit organizations. However, grants for research conducted in the facilities of business firms should not be precluded. For certain kinds of projects, industry facilities and participation may be very important.[108a]

The research support program of the Institute undoubtedly would overlap the scope of the engineering sciences support program of the National Science Foundation, and in some cases the basic research program of mission-oriented Government agencies like the DOD. For experimental hardware projects there would be some overlap with mission-oriented Government agencies, if not with the National Science Foundation, although this should not present a problem. Presumably the Institute would avoid projects where other financing was readily attainable and, in any case, multiple alternative sources of support for this kind of work are to be highly desired. When the National Science Foundation was established there were major alternative sources of Government basic research support, and the NSF continues to be a small-scale supporter of basic research, relative to such organizations as the DOD, NASA, AEC, and HEW. The principal distinguishing function of the Institute, like the distinguishing characteristics of the NSF, would be the responsibility for across-the-board support of a particular class of

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[108a] Under these circumstances, the following conditions might be imposed to assure that the knowledge entered the public domain. The project must be run jointly by a university and a business firm or group of firms with a university person in at least joint project directorship. The research project should be separated physically from any proprietary work to assure that there are no constraints on visiting and observing. Finally, the academic group would have authority over the project write-up and reporting. However, setting these restrictions might preclude certain useful projects, and an agreement that results be fully published and that patent rights vested with the public may be sufficient.

activity. While the NSF is concerned with advancing the frontiers of science, the Institute would be concerned with advancing the frontiers of technology.[109]

2. TECHNOLOGY PACKAGING FOR PUBLIC NEEDS

One of the benefits which can be sought without argument is the use of accumulated federally sponsored technology in other newly developing public purpose programs. These include the restoration of environmental quality, pollution abatement, crime prevention, urban mass transportation, arms control and disarmament, highway safety, worldwide nutrition, and urban redevelopment. The Department of Commerce Panel on Invention and Innovation reports:

> Any consideration of the total innovative process should include analysis of the interrelations between social and private innovation. Private innovation in the industrial sector has produced conditions which call for social innovation in the public sector. Moreover, advances in private innovation are dependent upon the climate provided by social innovation.
>
> We have considered the possible sources of social innovation and the roles of government and industry with respect to its performance. Social innovation in the public sector must depend upon private as well as public resources. As an illustration, improvements in the control of water and air pollution must stem from private innovations producing changes in automobiles and in industrial processes such that the polluting elements which are discharged into the environment will be reduced or eliminated.
>
> We believe it is incumbent upon government, both local and national, to provide the essential framework for social innovation. As a general principle, moreover, government should encourage the use of private resources for social innovation whenever possible. In this effort we conceive of governmental functions along the following lines:
>
> (*a*) Defining the social problems and the priorities for their solutions.
>
> (*b*) Intensifying the planning for such solutions.
>
> (*c*) Encouraging private enterprise to seek profitmaking opportunities in the development of such solutions.
>
> (*d*) Developing regulatory and other mechanisms, such as government purchasing policies, to compel or encourage industries to modify productive processes and products in such ways that they will contribute to the betterment of the social sector (for example, regulations regarding water and air pollution).
>
> (*e*) Carrying on the necessary technological developments, when it is clear that private resources cannot be depended upon to undertake them satisfactorily.[110]

Technology transfer could provide an important additional Government function in assembling special packages of federally controlled technology which are important to the desired social innovation. For example, the electric automobile might be an attractive alternative to the internal combustion engine powered car for certain urban uses. The Government is not likely to contract directly for the development of an electric auto. Pollution abatement legislation may strengthen the market demand and stimulate private R. & D. Such efforts could be launched from a higher state of the art if all the scientific and technical knowledge from Federal programs which was relevant to electric propulsion was made readily available to private developers. A Federal technology transfer program could retrieve and organize these data with the end use clearly in mind. Industrial developers would not have to make repetitive searches individually. The existence of such a specialized technological package would accelerate innovation toward meeting this well-defined public need.

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[109] "Technology, Economic Growth and Public Policy," Nelson, Richard R.; Peck, Merton J.; and Kalachek, Edward D. The Brookings Institution, Washington, D.C., 1967, p. 180, 181, 182.

[110] Op. cit., ref. 70, pp. 11, 12.

H. Technology Transfer by the U.S. Department of Agriculture

Any discussion of a purposeful program for moving scientific information into practical application soon involves the success story of American agriculture. Most of this sort of transfer is the direct and primary use of R. & D. which was performed for a well-recognized reason. But a significant amount of agricultural technology has found additional use far removed from the original project. And most importantly, the Government was acquiring the technology but the thousands of individual farmers were the appliers. So an efficient and widespread transfer system was developed. The concept of the extension agent seems quite relevant to industrial technology transfer.

The following description is presented so that valid extrapolations can be made and also to show where the analogy breaks down. This section was furnished to the subcommittee by the USDA.

1. Introduction

The collection and dissemination of information on agricultural technology has been a national policy of the U.S. Government since the early days of the Republic. George Washington in his last annual message to Congress stressed the "primary importance" of agriculture to the national welfare and observed that among the means used to promote agricultural development—

"* * * none have been attended with greater success than the establishment of boards (composed of proper characters) charged with collecting and diffusing information, and enabled by small pecuniary aids to encourage and assist a spirit of discovery and improvement".

Funds from the first appropriation for agriculture made to the Patent Office in 1837 were used not only to acquire knowledge, but also to finance the publication of information on agricultural subjects including technology. Trained writers were employed for this purpose, a practice that has continued to the present.

The act establishing the U.S. Department of Agriculture in 1862 directed that the new agency "acquire and diffuse among the people of the United States useful information on subjects connected with agriculture in the most general and comprehensive sense of that word * * *"

It also directed "* * * the Commissioner of Agriculture to acquire and preserve in his Department all information concerning agriculture which he can obtain by means of books and correspondence, and by practical and scientific experiments * * *."

From the beginning, the Department defined its responsibility to inform the people in the broadest sense. The Department not only publishes the results of research in scientific journals or monographs; it also accepts the responsibility of communicating research findings in forms that can be understood and used by farmers and the general public.

The Department maintains an "open door" information policy. Requests for information are freely filled, subject only to certain legal restrictions or departmental regulations. Representatives of the communications media are encouraged to interview policy, administrative, or technical personnel without restriction.

As a result of the policy laid down in legislation enacted over a century ago, the Department now has the most comprehensive system for technology transfer of any department of Government. It is based on the following: (1) Publications; (2) dissemination of scientific and technology findings through the mass communications media; (3) Agricultural Extension; and (4) the National Agricultural Library.

2. PUBLICATIONS

In line with its historic mission, USDA has developed an extensive publications program for transfer of the technology developed in its laboratories and experimental farms to those who produce and market the Nations's food and fiber. The Department at its Washington headquarters (including Beltsville), issues about 1,100 scientific and technical publications annually. In addition, up to a thousand recurring reports each year present economic, statistical, and market information necessary for the operation of modern agricultural industry.

The USDA has long followed a policy of adapting its publications to the needs of the users. Several publication series have been developed, each designed for the requirements of a defined readership (See attachment). Thus, the findings of a particular research project may be published in a technical bulletin written primarily for scientists or specialists; be the basis for a nontechnical article for the general public in one of the Department's periodicals, and presented in a farmers' bulletin written specifically to inform farmers and ranchers how they may put the findings into practical use on the farm. (Other outlets such as Extension, mass media, and the National Agricultural Library are discussed below).

A citizen can obtain free a single copy of most USDA publications as long as the supply last. However, priority is given to libraries, universities, cooperators, and the communications media which can further disseminate the information. Most major USDA publications also are sold by the Superintendent of Documents.

The Department's publications for the most part originate in the several agencies of the Department, such as the Agricultural Research Service, the Economic Research Service, or the Forest Service. Here the manuscripts are planned and prepared, and the publications financed. Several other functions are centralized in staff offices of the Department, principally the Office of Information, so that USDA has a coordinated publications program rather than an aggregate of separate agency publications programs.

The Office of Information provides policy review and control of all manuscripts and coordinates interagency and inter-Department aspects. It provides illustrations and design service in the preparation of manuscripts for publication, and handles arrangements for printing.

Many USDA bulletins reporting research findings derive from projects conducted cooperatively by the Department and the State Agricultural Experiment Stations. The results of such cooperative research projects may be published by either the States of USDA.

While Department bulletins are used in publishing more complete findings of research, extensive reporting of research results is done also through professional journals. Upward of 3,500 articles by Department researchers appear in scientific journals each year. Separates, or prints, of these articles are commonly used in limited quantity by the Department in communicating this information beyond the readers of the journals.

Department scientific and technical publications which originate in the field and are primarily for use in the geographical area of origin are published in the field.

In addition to the formal publication program of USDA, a great deal of information on science and technology is disseminated to the public through personal contacts—letters, telephone calls, visits, and speeches. Concurrent programs of research in the several State agricultural experiment stations, many of which are cooperative with USDA, are yielding an impressive body of scientific information. This involved in fiscal year 1965 over 8,000 articles in scientific journals, over 1,100 technical reports in station bulletins and periodicals, and some 2,500 popular bulletins and circulars. New information thus released by the experiment includes the results of research supported by Federal grants and contracts and by State funds. It is an important part of the new technology in agriculture.

3. MASS COMMUNICATIONS MEDIA

Press information

USDA provides research information to newspapers, magazines, and wire services through two principal channels: (1) Press releases, and (2) replies to direct inquiries and conferences, briefings, interviews, and tours.

Press releases issued on research projects include announcements of all USDA grants, research contracts, and cooperative research agreements. Later, when research has been completed, agency information personnel carefully screen professional journal papers and write releases on those USDA-funded findings considered to have news value for the agricultural, trade, scientific, or general press. Several hundred such releases on agricultural and forestry research are written each year by USDA agencies and cleared and issued by the Office of Information. Additional releases on research are issued by State universities and land-grant colleges.

Research information is also made available to the press in response to direct inquiries by reporters, writers, and photographers. In many instances, the inquiries are made to USDA personnel in Washington, D.C.; many others are made directly to researchers at field installations or during their attendance at professional meetings. Frequently, press inquiries result in interviews with researchers and visits to research facilities. Less frequently, research information is disseminated to the press during press conferences, special briefings, and in public addresses by Department officials.

Other media

USDA also uses television programs and films, radio tapes and programs, motion pictures and slides, photographs and picture stories, and posters and exhibits to disseminate research information among agriculturalists and the general public.

In cooperation with WRC–TV and NBC, the Department of Agriculture produces two color programs each week: "Across the Fence," a half-hour show viewed in 15 major cities, and "Down to Earth," which is shown in 5-minute daily segments in a number of metropolitan areas. A large part of these shows consists of interviews with scientists and economists, who communicate the results of their research to the public. A number of additional television film features are produced annually by the research agencies and are then cleared by the Office of Information and distributed as public service announcements to nearly 400 television stations in the United States.

Scientific and technical information also forms a large part of Department radio programs. Each week, USDA produces "The American Farmer," a 25-minute show carried by 60 radio stations; "Agriculture USA," a 15-minute show used by 221 stations; "What Consumers Want to Know," a 30-minute show carried by 119 stations, and Agri-Tape, a series of features slanted to farm audiences which is mailed to from 500 to 550 stations. One Department research agency alone—the Agricultural Research Service—last year produced 184 radio tapes on scientific subjects for inclusion in these Department programs.

The Department also disseminates research information through motion pictures and slide sets or film strips accompanied by narratives. Audiences for these productions—schools, technical groups, service clubs, agricultural groups—are planned well in advance and distribution is made accordingly. USDA films are available from the Department in Washington and from the film libraries of State universities and land-grant colleges.

Photographs dealing with scientific subjects are made available to media by the Department on request. In addition, research agencies prepare a number of picture stories on technical subjects. These are cleared by the Office of Information and distributed to picture editors of daily newspapers, Sunday magazine sections, photomagazines, and syndicates.

Finally, a number of Department exhibits are built each year dealing with research subjects, and they are displayed at both professional meetings and at such public gatherings as State and county fairs. Posters, which are commonly used to disseminate research information of interest to farmers on plant pest control and animal diseases, are usually distributed by the field staffs of the regulatory agencies.

4. THE COOPERATIVE EXTENSION SERVICE

The Cooperative Extension Service was established by act of Congress in 1914. From the outset it has been a joint cooperative relationship between the Federal Extension Service in USDA and the State extension service, a division of the college of agriculture in each State land-grant university. Its work consists of giving instruction and practical demonstrations in agricultural and home economics and subjects relating thereto—and imparting information on said subject through demonstrations, publications, and otherwise; and for the necessary printing and distribution of [such] information.

The Cooperative Extension Service is devoting 8,580 man-years annually to the adaptation and application of science and technology to the farm business, involving planning production, management, and marketing. This includes plant and animal breeding, nutrition, disease and pest control, management, agricultural economics, and engineering. A portion of the time is devoted to assisting home-owners and off-farm clientele with agricultural problems. This includes use of insecticides, herbicides, and other pesticides in and around the home, work with gardeners, greenkeepers (golf courses), caretakers of cemeteries, athletic fields, highway officials on vegetative cover for roadsides, and horticultural work for nonbusiness purposes. These educational endeavors are all based on research findings.

Much of Extension's educational program is conducted through demonstrations, meetings, seminars, and workshops for clientele. Extension conducted 419,777 field trials and demonstrations to encourage application of research findings. It has held many indepth schools for special interest groups. For example: Regional schools are being held to train the aerial pesticide applicators that spray 66 million acres and account for 23 percent of all pesticides used in this country. Special attention is being directed to methods of controlling drift and obtaining precise application. Each year much of the Extension worker's time is used to assist individuals with their specific problems. Last year 20,780,903 such consultations held, most of which required the interpretation and adaptation of research findings.

Articles are in a constant flow to farm magazines, trade journals, radio, television, and the press. Last year 773,269 news releases were made for newspapers and magazines, 62,201,190 copies of publications were distributed, 812,077 radio broadcasts and 50,687 TV broadcasts were made to assist the public with agricultural and home economics problems.

5. NATIONAL AGRICULTURAL LIBRARY

The National Agricultural Library was established in 1862 as the library of the Department of Agriculture. Although it did not receive its "National" name until 1962, it has provided nationwide services since its inception. It serves not only the U.S. Department of Agriculture, but also the larger public to which the Secretary is responsive and responsible.

Our collections—approximately 1,263,000 volumes—constitute the largest agricultural library in this country. Access to this information is provided, to all who are seriously interested in any facet of agriculture, in a number of ways. These include:

(1) Lending publications.
(2) Answering questions (reference services).
(3) Providing photoreproduction.
(4) Issuing specialized bibliographies and lists.

Access is also provided through several publications. The monthly publication: "The National Agricultural Library Catalog" lists all titles added to the library collection during the previous month. Among these titles are most of the substantive publications of the Department and many of the State agricultural experiment stations and commercial agriculture and related institutions. Included also are publications constituting the final report of research performed under grant or contract, which is supported by U.S. Department of Agriculture funds.

A more comprehensive index to information currently added to the library's collection is our monthly "Bibliography of Agriculture," which cites annually more than 100,000 substantive books, journal articles, and reports. This bibliography is widely available through the 889 depository libraries in the United States, and by purchase from the Superintendent of Documents.

A specialized current-awareness publication is our biweekly "Pesticides Documentation Bulletin." This includes 33,000 citations annually, with availability similar to the "Bibliography of Agriculture."

All other substantive publications of the Department are also made available through these repository libraries.

The National Agricultural Library, the National Library of Medicine, and the Library of Congress constitute an informal, but recognized, national library system. An informal agricultural library network, involving the National Agricultural Library and the libraries of the land-grant institutions and other local libraries has been operating for many years. The services of this network are being strengthened through more formal arrangements.

The Department supported the legislation establishing, and cooperates with, the Federal Clearinghouse for Scientific and Technical Information, Department of Commerce. However, in recognition of the vast and efficient information services of the Departments of Agriculture and Health, Education, and Welfare, both of these Departments were specifically excluded from total and mandatory participation.

I. Assignment of Responsibilities

Table 7 shows the activities which are pursued by various institutions in the transfer process. The X's indicate a responsibility which is going on at present or is an obvious assignment. The questionable areas may be clarified in time by the results of ongoing experimental programs, by the subcommittee investigation, and by policy planning.

TABLE 7.—*Activities and institutions in technology transfer*

Activity	Originating laboratory	R. & D. agency sponsor	Information agency	Transfer agency	Private transfer institutions	Commercial business	Social institutions
Identification and reporting	X	X					
Screening and organization	X	X	X	?			
Storage, inventory, and retrieval		?	X	X	?		
Publication and dissemination	?	?	X	X	X	?	
Personal counseling and education				X	X		X
Application assistance	?			?	X	X	?
Innovation and demonstration					X	X	
Sales of goods, services, and processes						X	
Diffusion and social benefits				?	X	X	X

The originating laboratory must take on the function of identification and reporting although the individual researcher may be aided by specially trained "new technology" officers (see NASA system p. 122). In the case of Federal laboratories, the agency can provide this function. In industry the patent department may do the job along with their usual task of identifying inventions.

The screening of technology for application potential, and editing and organizing descriptions into concise, uniform terminology may be shared by the originating laboratory, the agency, or a specialized information center. Even the transfer agent can perform this function if it hasn't been done before the information gets to him. The preparation of survey reports or summaries of related technology is a part of this activity. It is important that the language of technology transfer documents be comprehensible to business management in addition to practicing scientists and engineers.

The establishment of a storage and retrieval center is primarily the duty of information and transfer agencies. If the sponsoring Federal department is large enough, it will probably have such an operation as part of its own R. & D. management process to use the research results for mission support. The capability can be expanded to serve technology transfer with little additional effort. If the technology is available from several small governmental programs, a private sector information handling system may acquire and store it for transfer purposes. However, up to this point in the overall process, the responsibility for the technology seems to lie with the sponsoring agency and its R. & D. performers.

Publication and dissemination may occur in a variety of forms—technical papers, progress reports, and patents from the sponsoring and performing organizations. After the technology has been packaged for transfer, dissemination is dependent on both Federal and private efforts. Transfer agents who are seeking to tie solutions to problems will be the main mechanism regardless of their actual employer. Industry itself may contribute to dissemination through licensing programs and the exploitation of technical positions.

Personal counseling, referrals, consulting, and the education of technically lagging industrial firms also will be accomplished largely by transfer agents. They may be supported by local initiative in regional development programs, by forward looking companies who hire technology "prospectors" to ferret out new facts and knowledge to satisfy their needs; by university extension services with matching Federal and State funds or by research institutes. In the case of special fields (e.g., medicine) particular social service institutions may become the counseling organization.

Application assistance may require direct contact between the originator and the innovator. That is why technology must carry with it a clear record of where and by whom it has been developed. R. & D. management should devise a way for researchers to consult with application technologists with some equitable compensation. Federal employees can be encouraged to do so on a basis of noninterference with their primary tasks. Contractor employees may be put in a position of consulting with a competitor who wishes to exploit the technology originated under Government sponsorship. A minute misinterpretation or error in impersonal communication may render the technology useless without recourse to the research scientist who began the development. Observers have stated that Russia inserts unlabeled material into a centralized technical information system (presumable to disguise its origin in space-military-nuclear weapons programs). But this technology reportedly is scorned by applications engineers because of the inability to check back with the inventor.

At the application, innovation, and demonstration phase, the transition from Federal to private responsibility becomes blurred and this is where policy guidance is most needed. Should the Government take technology a little further toward proof of concept than would be warranted for the sake of the principal mission? It might be much more economical and timesaving to do this at the end of an agency program than to turn the half-developed work over to industry which would have to organize and equip a development team to complete the job. Should industry be able to step into Federal or contractor operations to carry on technology which cannot be justified for Government support? Should technology of broad applicability to recognized industrial needs be sponsored by the Government if the particular user industry is too fragmented to organize for support? The Department of Agriculture, through its regional utilization laboratories, continuously develops new products and processes for farm produce. These manufacturing methods are licensed to private industry. The Bureau of Mines develops extractive metallurgy and other processes related to fossil fuels and minerals with the expectation that private firms will ultimately use the technology. Do thsee instances constitute precedents for Federal underwriting of further development of military/space information for civilian use? These questions have been answered in various ways in certain instances, but never in the form of policy guidance.

Sales and profits are clearly the function of the private commercial sector. On the other hand, the diffusion of successful innovations can be accelerated by the activities of several institutions, each with their own logic and motive.

Therefore, the principal policy questions of jurisdiction and responsibility are:

1. Where should individual Federal agency technology transfer activities be merged into a single governmentwide industry contact function;
2. Where should Federal support of the transfer process stop and private determination begin as to whether to use or not to use the technology.

It seems unnecessary and confusing to have each R. & D. agency proffering its technology to business. However, some would argue that to interpose a central Federal transfer agency between originator and user simply cuts the efficiency down further.

The support, by the Government, of development for industrial use necessarily involves a choice among many candidate ideas. When these choices are made within a bureaucracy without the risk-profit motive of the marketplace, they are likely to be less than optimum.

Throughout the entire process, policy must allow for proprietorship and due reward for extra investment beyond the original Federal contract requirement. At the same time the social benefits from publicly funded R. & D. results must be stimulated.

[illegible]

X. ANALYSIS OF AGENCY OPINIONS ON TECHNOLOGY TRANSFER

The subcommittee has surveyed the major Federal agencies which support R. & D. The following questions were asked:

1. Under what statutory or other authority does your department operate for the identification, collection, organization, dissemination, and application of technology acquired in support of your mission?

2. What is your judgment with respect to the applicability and value of such technology to: (*a*) your agency; (*b*) other Federal agencies; and (*c*) the private industrial sector?

3. When this technology is developed in the course of federally funded research and development projects (intramural or via grants or contracts), what policies and procedures do you follow with respect to: (*a*) Identification and reporting; (*b*) organization and evaluation; (*c*) publication and dissemination; and (*d*) the active pursuit of new applications?

4. Discuss your views of the need, desirability, and practicality of establishing a uniform, Government-wide policy governing the use of such technology.

5. What is your view of establishing, in a combined, centralized organization, the handling of all phases of such technology?

6. What are your views on the following suggested concepts for technology transfer:

   (a) A legislatively chartered Comsat-type corporation to use private financing for the exploitation of federally owned technology.

   (b) Individual State programs, partially funded by the Federal Government, which would perform the dissemination and application activity. Such State efforts would be coupled to one unified Federal collection and processing organization which would receive new technology from all Federal agencies.

The replies have been analyzed and summarized for each question. Dr. Donald F. Hornig, Director of the Office of Science and Technology in the Executive Office of the President, stressed the need for ideas and experiments in encouraging wide application of science to growing public and private needs. He told the subcommittee:

> What evidence we have suggests that the process of technological change is quite healthy—we do not face a crisis on this score. In fact our competitive advantage in products incorporating advanced technology and our commanding position with regard to world patent rights has led many European countries to protest about a growing "technology gap." I believe that further study will disclose that our favorable international position has been established as a result of two key factors. We have outstanding industrial and academic research capability which produces new information and trains new technical manpower. Second, we have aggressive industrial leadership in most sectors which is prepared to face up to the arduous, risky task of innovation. One might say that we have a strong research "push" and an equally strong entrepreneurial or market "pull."
>
> * * * * * * *
>
> Finally, I would suggest that the information transfer task is only one part and perhaps a minor part of a larger issue of technological progress. The information task is one of more clearly identifying user needs and finding more efficient long run solutions rather than a forced draft search for a workable short term arrangement.

A. Federal Research on the Transfer Process

Some critics of the current technology transfer programs suggest that more study of the process is in order before action is taken. The subcommittee inquired of the National Science Foundation as to what research it had supported in this field. A substantial amount of empirical economic data has been correlated with technological factors. The NASA and DOC programs are experimental themselves and will be subject to interpretive study as they progress.

The agencies appear to have adequate authority to study the transfer process although funding may be less available than some would desire. Dr. Leland Haworth, Director of NSF, wrote:

> We are pleased to supply the information requested in your letter of January 23, 1967, dealing with NSF funding of studies into the relationship of R. & D. to economic growth and the processes and techniques of technology transfer. These are not clearly defined areas and many NSF-supported studies and research may touch upon them.
>
> For the fiscal years 1963–67, the Foundation committed $890,000 for the types of studies referred to in your inquiry. The attached exhibit 1 lists these projects with names of the principal investigators, their organizations, and the amount and year of initial funding. I have not included projects concerned with R. & D. expenditures and scientific manpower although such studies may sometimes provide data cited in studies of technology transfer.

EXHIBIT 1—STUDY TITLES CONCERNED WITH R. & D. AND ECONOMIC GROWTH AND THE TECHNIQUES OF TECHNOLOGY TRANSFER, FISCAL YEAR 1963–FISCAL YEAR 1967, FUNDED BY THE NATIONAL SCIENCE FOUNDATION

1. A study of the impact of research, development, and innovation upon the economic development and general welfare of the United States.
Principal investigator: Profs. Edwin Mansfield and Norton Seeber, Carnegie Institute of Technology. Funding total, $24,520, fiscal year 1963.

2. Econometric Studies of Research and Development.
Principal investigator: Prof. Edwin Mansfield, Carnegie Institute of Technology. Funding total, $113,600, fiscal year 1963.

3. An Empirical Study of Technological Change.
Principal investigator: Prof. A. H. Conrad, Harvard University. Funding total, $12,200, fiscal year 1963.

4. A study of the capacity of industrial firms to absorb and apply the results of scientific activity. (Final report being prepared.)
Principal investigator: Dr. Sumner Myers, National Planning Association. Funding total, $243,000, fiscal year 1963.

5. A study of the process of technical innovation in American industry.
Principal investigator: Dr. Donald Schon, Arthur D. Little, Inc. Funding total, $22,000, fiscal year 1963.

6. Economic Theory of Technological Change.
Principal investigator: Prof. R. E. Lucas, Carnegie Institute of Technology. Funding total, $17,400, fiscal year 1964.

7. A study of the role of changing regional patterns of research and development and science-based technology in influencing regional development (exploratory study).
Principal investigator: Prof. Charles Stewart, George Washington University. Funding total, $48,764, fiscal year 1964.

8. The role of research and development and research-based manufacture in the economy of Utah, Santa Clara County, Calif., and Winston-Salem, N.C.
Principal investigator: Prof. Charles Stewart, George Washington University. Funding total, $55,322, fiscal year 1965.

9. Technical Change and Capital Output Relations.
Principal investigator: Prof. M. Gort, Research Foundation of the State University of New York. Funding total, $24,400, fiscal year 1965.

10. An Empirical Study of Technological Change.
Principal investigator: Prof. Murray Brown, George Washington University. Funding total, $26,400, fiscal year 1965.

11. Econometric Investigations of Technological Change.
Principal investigator: Prof. Zvi Griliches, University of Chicago. Funding total, $72,300, fiscal year 1965.

12. Investment Theory and Technical Progress.
Principal investigator: Prof. R. Eisner, Northwestern University. Funding total, $120,000, fiscal year 1965.

13. The Theory of Induced Technical Change.

Principal investigator: Profs. M. I. Kamien and N. L. Schwartz, Carnegie Institute of Technology. Funding total, $42,400, fiscal year 1966.

14. Feasibility studies of development methodology for projecting the economic and social implications of a potential scientific innovation.

Principal investigator: James Hacke, Stanford Research Institute. Funding total, $68,131, fiscal year 1967.

B. Statutory Authority for Processing New Technology, Question 1

All agencies consider the handling and processing of scientific and technical information as a part of authority to perform R. & D. in support of their mission. All agencies encourage the routine publication of scientific papers. NASA has interpreted the Space Act to allow the technology utilization program to the extent that it is supported by annual budget authorization and appropriation. The Department of Commerce has broad authority to aid business and specific responsibility for the State Technical Services Act program to transfer technology. The AEC has interpreted its enabling act to include dissemination of nuclear and nonnuclear technology. Other agencies have not identified an obligation to foster additional applications outside their routine operations, for example, the Department of Agriculture Extension Service.

Statutory references provided by the agencies are reproduced as follows:

1. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The National Aeronautics and Space Act of 1958, as amended establishes the policy that the aeronautical and space activities of the United States shall be conducted so as to contribute materially to * * * the expansion of human knowledge of phenomena in the atmosphere and space * * * the establishment of long-range studies for the potential benefits to be gained from * * * the utilization of aeronautical and space activities for peaceful and scientific purposes * * * and * * * the most effective utilization of the scientific and engineering resources of the United States with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities and equipment (72 Stat. 427). The act also provides that the National Aeronautics and Space Administration—to carry out the purposes of this act, shall * * * arrange for participation by the scientific community in planning scientific measurements and observations * * * and * * * provide for the widest practical and appropriate dissemination of information concerning its activities and the results thereof (72 Stat. 429).

2. DEPARTMENT OF COMMERCE

The Department was designated as such by the act of March 4, 1913 (37 Stat. 736; 5 U.S.C. 591 (1964 ed.)). It operates under a very broad mandate to foster, promote, and develop the foreign and domestic commerce; and the manufacturing, transportation, and shipping industries of the United States (5 U.S.C. 596 (1964 ed.)). In responding to this mandate, the Department is deeply concerned with the acquisition, transfer, and exploitation of technology.

The National Bureau of Standards, for example, is responsible for maintaining a complete and consistent national system of physical measurement and constants. The Bureau also develops standard methods for testing materials, mechanisms, and structures (see 31 Stat. 1449, as amended; 15 U.S.C. 271–86). The technology developed within the Bureau is disseminated through many channels. One such channel is in the form of calibration services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce (see 15 U.S.C. 272(6)). More generally, the NBS is responsible for the compilation and publication of general scientific and technical data resulting from the performance of its own functions and from other sources "when such data are of importance to scientific and manufacturing interests or to the general public, and are not available elsewhere" (see 15 U.S.C. 272(19)). The Department's Clearinghouse for Federal Scientific and Technical Information is located within the NBS. It has responsibility for collecting, organizing, and publicizing unclassified Government-generated technical reports to American commerce, industry, and business. This responsibility is set forth in 15 U.S.C. 1151 and 1152 as follows:

SEC. 1151. The purpose of this chapter is to make the results of technological research and development more readily available to industry and business, and to the general public, by clarifying and defining the functions and responsibilities of the Department of Commerce as a central clearinghouse for technical information which is useful to American industry and business.

SEC. 1152. The Secretary of Commerce (hereinafter referred to as the "Secretary") is directed to establish and maintain within the Department of Commerce a clearinghouse for the collection and dissemination of scientific, technical, and engineering information, and to this end to take such steps as he may deem necessary and desirable—

(a) To search for, collect, classify, coordinate, integrate, record, and catalog such information from whatever sources, foreign and domestic, that may be available;

(b) To make such information available to industry and business, to State and local governments, to other agencies of the Federal Government, and to the general public, through the preparation of abstracts, digests, translations, bibliographies, indexes, and microfilm and other reproductions, for distribution either directly or by utilization of business, trade, technical, and scientific publications and services;

(c) To effect, within the limits of his authority as now or hereafter defined by law, and with the consent of competent authority, the removal of restrictions on the dissemination of scientific and technical date in cases where consideration of national security permit the release of such data for the benefit of industry and business.

The Environmental Science Services Administration (ESSA) is another source of scientific and technical data of interest to many industries. It was established on July 13, 1965, through consolidation of the Coast and Geodetic Survey and the Weather Bureau (Reorganization Plan No. 2 of 1965). ESSA makes available technical data on the state of the oceans, the state of the upper and lower atmosphere, and the size and shape of the earth.

The Patent Office, in addition to administering the laws relating to the registration of patents and trademarks, publishes and disseminates patented matter, and records the assignment of patents. Its scientific library and search file of U.S. and foreign patents constitute a valuable source of technological data (see 66 Stat. 792; 35 U.S.C. 1–293, and 60 Stat. 427; 15 U.S.C. 1051, as amended, for the statutes relating to patents and trademarks, respectively).

Under title III of the Public Works and Economic Development Act of 1965 (79 Stat. 552; 42 U.S.C. 312), the Economic Development Administration provides technical assistance to help distressed areas. Such assistance may involve direct contact through the EDA staff, or contract with expert consultants. It may also be in the form of technical assistance in planning grants-in-aid to eligible States, districts, and local organizations.

The State Technical Services Act of 1965 (79 Stat. 679; 15 U.S.C. 1351) is perhaps the most recent addition to the Department's statutory authority in the area of technology transfer. Under this act, the Secretary is authorized to support State designed and administered technical services programs to place the results of science and technology usefully in the hands of American enterprise. Although the act includes the dissemination of Government-generated science and technology, it is not limited to it. It provides for the States themselves, acting through their designated agencies and participating institutions, to determine their own local technological needs and interests. This program, therefore, focuses on the receiving end of technology transfer, and completes the cycle from technology producer to technology consumer. The act is administered by the Department's Office of State Technical Services.

3. ATOMIC ENERGY COMMISSION

Certain paragraphs contained in the Atomic Energy Act of 1954 provide the general basis for the information activities of the Commission.

Section 1, "Declaration," for instance, outlines the general policy as follows:

> Atomic energy is capable of application for peaceful as well as military purposes. It is therefore declared to be the policy of the United States that—
>
> (*a*) the development, use, and control of atomic energy shall be directed so as to make the maximum contribution to the general welfare, subject at all times to the paramount objective of making the maximum contribution to the common defense and security; and
>
> (*b*) the development, use, and control of atomic energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise.

Under section 3, "Purpose," we find the following statement:

> It is the purpose of this Act to effectuate the policies set forth above by providing for—
>
> (*b*) a program for the dissemination of unclassified scientific and technical information and for the control, dissemination, and declassification of Restricted Data, subject to appropriate safeguards, so as to encourage scientific and industrial progress; * * *

This purpose is stated a little more fully in section 141.

> Sec. 141. Policy. It shall be the policy of the Commission to control the dissemination and declassification of Restricted Data in such a manner as to assure the common defense and security. Consistent with such policy, the Commission shall be guided by the following principles:
>
> (*b*) the dissemination of scientific and technical information relating to atomic energy should be permitted and encouraged so as to provide that free interchange of ideas and criticism which is essential to scientific and industrial progress and public understanding and to enlarge the fund of technical information.

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Bureau of Mines

The Bureau of Mines fulfills its mission under the authority of Public Law 179 approved May 16, 1910, which established the Bureau of Mines in the Department of the Interior. An amendment to this act, Public Law 386, approved February 25, 1913, sets forth this charter which reads in part as follows:

SEC. 2. That it shall be the province and duty of the Bureau of Mines, subject to the approval of the Secretary of the Interior, to conduct inquiries and scientific and technologic investigations concerning mining, and the preparation, treatment, and utilization of mineral substances with a view to improving health conditions, and increasing safety, efficiency, economic development, and conserving resources through the prevention of waste in the mining, quarrying, metallurgical, and other mineral industries; to inquire into the economic conditions affecting these industries; to investigate explosives and peat; and on behalf of the Government to investigate the mineral fuels and unfinished mineral products belonging to, or for the use of, the United States, with a view to their most efficient mining, preparation, treatment and use; and to disseminate information concerning these subjects in such manner as will best carry out the purposes of this Act.

SEC. 3. That the director of said bureau shall prepare and publish, subject to the direction of the Secretary of the Interior, under the appropriations made from time to time by Congress, reports of inquiries and investigations, with appropriate recommendations of the Bureau concerning the nature, causes, and prevention of accidents, and the improvement of conditions, methods, and equipment, with special reference to health, safety, and prevention of waste in the mining, quarrying, metallurgical, and other mineral industries; the use of explosives and electricity safety methods and appliances, and rescue and first-aid work in said industries; the causes and prevention of mine fires; and other subjects included under the provisions of this Act.

Through subsequent legislative acts, the Congress has further authorized the Bureau of Mines to assist in providing, at the lowest possible cost, supplies of mineral raw materials adequate to the needs of the civilian economy. Over the nearly 56 years of its existence, the Bureau has been given responsibility for a variety of activities. These are as follows:

(*a*) Under authority of Public Law 68–544, approved March 3, 1925, as amended by Public Law 86–777, dated September 13, 1960, the Bureau produces virtually all of the free world's current supply of helium from natural gas. The Bureau also is engaged with private enterprise in a long-range helium conservation program to recover and store underground, for future use after 1985, about 40 billion cubic feet of helium which otherwise would be lost in the natural gas being consumed for industrial and residential purposes.

(*b*) Federal inspections and investigations at coal mines are conducted in accordance with provisions of Public Law 89–376, approved March 26, 1966, the Federal Coal Mine Safety Act, as amended.

(*c*) The responsibility for inspection and investigation of metal and nonmetal mines is provided in Public Law 89–577, approved September 16, 1966, the Federal Metal and Nonmetallic Mine Safety Act.

(*d*) Research into the problems of solid waste disposal to develop new and improved methods for utilizing solid mineral and metal waste materials or to dispose of them in the most practicable way is authorized under Public Law 89–272, approved October 20, 1965, which amends the Clean Air Act.

Office of Coal Research

The statutory authority under which the Office of Coal Research operates is Public Law 86–599 (74 Stat. 336) section 1(b), section 2, section 5, and section 6.

Federal Water Pollution Control Administration

Under section 5a of the Federal Water Pollution Control Act, as amended, the Secretary is authorized to collect and make available through publication and other appropriate means, the results of and

Large numbers of laws resulting in federally supported programs involving the "application" of technology have been enacted since the Department was established. Some examples are:

Federal Insecticide, Fungicide, and Rodenticide Act as amended in 1959, 1961, and 1964, 7 U.S.C. 135, and others.

National Forest Administration Act, 16 U.S.C. 473–478, 479–482, and 551.

Soil Conservation and Domestic Allotment Act, 16 U.S.C. 590 act for the control and eradication of certain animal diseases, 21 U.S.C. 114.

6. DEPARTMENT OF THE INTERIOR

Office of Saline Water

The Office of Saline Water's basic authority for operation is contained in the act of July 3, 1952 (66 Stat. 328), as amended (42 U.S.C. 1951 et seq.). Among other things, this act provides that the Secretary of the Interior shall:

SEC. 2. (g) Assemble and maintain pertinent and current scientific literature, both domestic and foreign, and issue bibliographical data with respect thereto; * * *

(i) foster and participate in regional, national, and international conferences relating to saline water conversion;

(j) coordinate, correlate, and publish information with a view to advancing the development of low-cost saline water conversion projects; and

(k) cooperate with other Federal departments and agencies, with State and local departments, agencies, and instrumentalities, and with interested persons, firms, institutions, and organizations.

SEC. 4 (a) Research and development activities undertaken by the Secretary shall be coordinated or conducted jointly with the Department of Defense to the end that developments under this Act which are primarily of a civil nature will contribute to the defense of the Nation and that developments which are primarily of a military nature will, to the greatest practicable extent compatible with military and security requirements, be available to advance the purposes of this Act and to strengthen the civil economy of the Nation. The fullest cooperation by and with Atomic Energy Commission, the Department of Health, Education, and Welfare, the Department of State, and other concerned agencies shall also be carried out in the interest of achieving the objectives of this Act.

(b) All research within the United States contracted for, sponsored, cosponsored, or authorized under authority of this Act, shall be provided for in such manner that all information, uses, products, processes, patents, and other developments resulting from such research development by Government expenditure will (with such exceptions and limitations, if any, as the Secretary may find to be necessary in the interest of national defense) be available to the general public. This subsection shall not be so construed as to deprive the owner of any background patent relating thereto of such rights as he may have thereunder * * *.

SEC. 6. The Secretary shall make reports to the President and the Congress at the beginning of each regular session of the action taken or instituted by him under the provisions of this Act and of prospective action during the ensuing year.

In addition, the Office of Saline Water was given the authority to construct demonstration plants under the joint resolution of September 2, 1958 (72 Stat. 1707), as amended (42 U.S.C. 1958 et seq.). In that joint resolution, the following requirement is included:

SEC. 2. * * * Any such operation and maintenance contract shall provide for the compilation by the contractor of complete records with respect to operation, maintenance, and engineering of the plant or plants specified in the contract. The records so compiled shall be made available to the public by the Secretary at periodic and reasonable intervals with a view to demonstrating the most feasible existing processes for desalting sea water and treating brackish water. Access by the public to the demonstration plants herein provided for shall be assured during all phases of construction and operation subject to such reasonable restrictions as to time and place as the Secretary of the Interior may require or approve.

4. DEPARTMENT OF DEFENSE

The Department of Defense's authority for the identification, collection, organization, dissemination, and application of scientific and technical information is derived solely from the provisions of title 10, United States Code, defining the Department's responsibility to perform necessary research and development in connection with its mission. Although there exist no specific provisions within title 10 dealing with the handling of defense-generated scientific and technological information, it is the policy of the Department of Defense to pursue a vigorous and thoroughly coordinated comprehensive technical information program, to the maximum extent permitted by security, which provides for the interchange of technical information within the Department, with its contractors, with other Federal agencies and their contractors, and with the scientific community as a whole.

The Department of Defense as a member of the executive branch, in addition to the programs initiated within the Department, is also required to cooperate and assist the Department of Commerce and the National Science Foundation with their respective scientific information activities. The Secretary of Commerce, for example, is authorized under chapter 23, title 15, United States Code, to call upon the Department for assistance in maintaining a clearinghouse for technical information and making such information readily available to industry and the general public. Similarly, Executive Order 10521, March 17, 1954, as amended by Executive Order 10807, March 13, 1959, requires that the head of each Federal agency engaged in scientific research shall make certain that effective organizational practices exist to insure that adequate dissemination of technical information is made within the Federal Government, and to cooperate with the National Science Foundation in improving methods of classification and reporting of such technical information and, finally, to assist the Foundation in its scientific information activities under section 1876, title 42, United States Code.

5. DEPARTMENT OF AGRICULTURE

The Organic Act of May 15, 1862, R.S. section 520 (formerly 5 U.S.C. 511) specified "There shall be . . . a Department of Agriculture, the general design and duties of which shall be to acquire and diffuse among the people of the United States useful information on subjects connected with agriculture, in the most general and comprehensive sense of the word . . ."

The basic authority of the Department has been strengthened and enlarged by many statutes, a few of which are cited here. Major laws amplifying research and development and extension aspects of the Organic Act resulting in the "identification, collection, organization and dissemination" of technological information are:

Hatch Act 7 U.S.C. 361 (Formula grants to State Agricultural Experiment Stations).

Research and Marketing Act, 7 U.S.C. 427, 427i, and 1292 (Production and utilization research, including authority for research contracts and cooperative marketing research).

Smith-Lever Act, as amended in 1953, 7 U.S.C. 341–349 and others (Agricultural Extension). Public Law 89–106, 7 U.S.C. 4506 (Authority for research grants).

other information as to research, inventions and demonstrations relating to the prevention and control of water pollution. Upon request, the Secretary may also conduct research and investigations and may survey any special problems confronting State, interstate, municipality, community and industrial plants with a view of recommending a solution to such problems. Under section 5c, the Secretary, in cooperation with other Federal, State, and local agencies having related responsibilities, is authorized to collect and disseminate basic data on chemical, physical, and biological water quality and other information insofar as such data or other information relate to water pollution and the prevention and control thereof. Furthermore section 5d charges the Secretary with responsibility for developing and demonstrating under varied conditions practicable means of treating municipal sewage and other waterborne wastes to remove the maximum possible amounts of physical, chemical, and biological pollutants in order to restore and maintain the maximum amount of the Nation's water at a quality suitable for repeated reuse and section 6 authorizes the Secretary to make grants to any State, municipality, of intermunicipal or interstate agency to achieve the above objectives. Section 6b of title II of the Clean Water Restoration Act of 1966 extends this granting authority to persons for research and demonstration projects for the prevention of pollution of waters by industry including, but not limited to, treatment of industrial waste.

7. FEDERAL AVIATION AGENCY

Statutory obligation for engaging in technological pursuit is primarily contained in section 312 of title III, Public Law 85–726, Federal Aviation Act of 1958. Obligation for the collection and dissemination of information is contained in section 302(d) and section 311, the former for exchange between the FAA and other Government agencies and the latter for exchange between the FAA and domestic interests and foreign governments.

8. THE DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

The authority of the several operating agencies of the Department of Health, Education, and Welfare for the identification, collection, organization, dissemination, and application of technology is discussed below.

Public Health Service

The authority of the Public Health Service in this area is derived basically from section 301 of the Public Health Service Act, as amended (42 U.S.C. 241; Reorganization Plan No. 3 of 1966, 31 Fed. Reg. 8855), which authorizes the Secretary to conduct and support research relating to the diseases and impairments of man. The Secretary is authorized to disseminate information as to such research and its practical application.

There are additional provisions in the Public Health Service Act authorizing research, information gathering, and dissemination activities. These provisions include section 311 of the Public Health Service Act, as amended (42 U.S.C. 243; Reorganization Plan No. 3 of 1966), which authorizes the Secretary to assist and cooperate with the States in public health matters; section 315 of the Public

Health Service Act, as amended (42 U.S.C. 247; Reorganization Plan No. 3 of 1966) which authorizes the Secretary to disseminate information related to public health; section 214(c) of the Public Health Service Act, as amended (42 U.S.C. 215(c); Reorganization Plan No. 3 of 1966), which authorizes the Secretary to detail personnel of the Service to nonprofit institutions engaged in health activities for special studies of scientific problems and for the dissemination of information relating to public health; section 217(c) of the Public Health Service Act, as amended (42 U.S.C. 218(c); Reorganization Plan No. 3 of 1966), which authorizes the National Advisory Mental Health Council to collect information on studies in the field of mental health health and, with the approval of the Secretary, to make available such information for the benefit of health and welfare agencies, physicians and other scientists, and for the information of the general public; section 305 of the Public Health Service Act, as amended (42 U.S.C. 242c; Reorganization Plan No. 3 of 1966), which authorizes the Secretary to make national health studies and surveys, and to make available the results of such studies and surveys to interested governmental or other agencies, or to the public; section 372 of the Public Health Service Act, as amended (the National Library of Medicine Act, 42 U.S.C. 276; Reorganization Plan No. 3 of 1966), which directs the Secretary, through the National Library of Medicine, to make available medical and scientific materials; and sections 390-399b of the Public Health Service Act, as amended (the Medical Library Assistance Act of 1965, 42 U.S.C. 280b-280b-11; Reorganization Plan No. 3 of 1966), which authorizes the Secretary (1) to make grants for the improvement of medical libraries, including the introduction of new technologies in medical librarianship; (2) to make grants for research and investigations in the field of medical library science and for the development of new techniques and equipment for processing, storing, retrieving, and distributing information on the health sciences; and (3) to provide support for biomedical scientific publications and for the preparation and publication of materials pertaining to scientific works and developments. The several Institutes of the National Institutes of Health and their Advisory Councils also have specific statutory authority to collect and disseminate information and materials (42 U.S.C. 281-289g).

In addition to the provisions of the Public Health Service Act referred to above, two other statutes administered by the Public Health Service contain provisions on the collection and dissemination of information. Section 204 of the Solid Waste Disposal Act (42 U.S.C. 3253) authorizes the Secretary to conduct and support research and studies relating to solid waste disposal, and to collect and disseminate information pertaining to such research and other activities, and requires that provisions be included in grants and contracts to insure that all information, uses, processes, patents, and other developments resulting from activities undertaken pursuant to such grants and contracts be made available to industries utilizing solid waste disposal methods and to industries which furnish equipment used in connection with solid waste disposal. Section 103 of the Clean Air Act, as amended (42 U.S.C. 1857b), directs the Secretary to establish a national research and development program for the prevention and control of air pollution, and authorizes him to collect and disseminate information on the prevention and control of air pollution.

Office of Education

The basic charter of the Office of Education (20 U.S.C. 1) provides for the diffusion of information respecting the organization and management of schools and school systems and methods of teaching. In addition, several of the statutes administered by the Office of Education include provisions for the dissemination of information. The Cooperative Research Act, as amended (20 U.S.C. 331(a)), authorizes the Commissioner of Education to support by grants, contracts, or jointly financed arrangements research, surveys and demonstrations in the field of education, and the dissemination of information derived from educational research. Title VII–B of the National Defense Education Act, as amended (20 U.S.C. 551), directs the Commissioner to disseminate information concerning new educational media to State or local educational agencies and to institutions of higher education. Section 224 of the Higher Education Act (20 U.S.C. 1034) authorizes the Commissioner to disseminate information derived from research and demonstrations relating to libraries and the training of library personnel.

Several educational assistance laws outside the research field also require or authorize recipients of Federal assistance to make available to others the results of research and demonstrations. These include section 205(a)(9) of Public Law 874, 81st Congress, as amended by section 111 of Public Law 89–750; section 503(a)(3, 5) of the Elementary and Secondary Education Act of 1965, as amended (20 U.S.C. 863(a)(3, 5)); and section 604(k) of the Elementary and Secondary Education Act of 1965, as added by Public Law 89–750.

Vocational Rehabilitation Administration

Section 4(a) of the Vocational Rehabilitation Act, as amended (29 U.S.C. 34(a)), authorizes the Secretary to make grants for research and demonstration projects, and projects for special facilities and services in the field of vocational rehabilitation. The Secretary is authorized by section 7(c) of the act (29 U.S.C. 37(c)) directly, or by contract, to conduct research, studies, investigations and demonstrations designed to promote the rehabilitation of the handicapped, and to disseminate information on such research and on rehabilitation resources. Section 7(a)(3) of this act (29 U.S.C. 37(a)(3)) requires the Secretary to disseminate information relating to vocational rehabilitation services.

Food and Drug Administration

The Food and Drug Administration is essentially a regulatory agency. The research conducted by FDA is designed to assist it in meeting its regulatory responsibilities. New instruments or methods of analysis which may be developed from such research are publicized through normal scientific channels of communication.

Section 705(b) of the Federal Food, Drug, and Cosmetic Act, as amended (21 U.S.C. 375) provides, in part, that the Secretary is not prohibited from collecting, reporting, and illustrating the results of the investigations of the Department.

Social Security Administration and Welfare Administration

Section 1110 of the Social Security Act, as amended (42 U.S.C. 1310) authorizes the Secretary to support by grants, contracts, or jointly financed arrangements research or demonstration projects in the fields of social security and public assistance, such as projects which relate to the prevention and reduction of dependency, or which will aid in effecting coordination of planning between private and public welfare agencies, or which will help to improve the administration and effectiveness of the social security and public assistance programs.

Title 42, United States Code section 192 directs the Children's Bureau to investigate matters pertaining to the welfare of children and child life, and authorizes the Chief of the Children's Bureau to publish the results of these investigations.

Section 533 of the Social Security Act, as amended (42 U.S.C. 729a) authorizes the Secretary to support by grants, contracts, or jointly financed arrangements research projects relating to maternal and child health services or crippled children's services.

Section 3 of the Juvenile Delinquency and Youth Offenses Control Act of 1961, as amended (42 U.S.C. 2542) authorizes the Secretary to make grants and contracts for demonstration and evaluation projects in the field of prevention and control of juvenile delinquency. Section 5 of that act (42 U.S.C. 2544) authorizes the Secretary to make studies in this field and to collect, evaluate, publish, and disseminate information relating to the prevention and control of juvenile delinquency.

Administration on Aging

Section 401 of the Older Americans Act of 1965 (42 U.S.C. 3031) authorizes the Secretary to make grants and contracts for studies and demonstration projects in the field of aging. Section 602 of that act (42 U.S.C. 3052) authorizes the Secretary to conduct research and demonstrations, and collect, prepare, publish, and disseminate special educational or information materials on the aging.

In addition to the statutory authorities cited above, the Public Health Service, Vocational Rehabilitation Administration, Welfare Administration, and Office of Education utilize foreign currencies pursuant to the provisions of section 104(b)(3) of the Agricultural Trade Development and Assistance Act of 1954, as amended (Public Law 89–808; 7 U.S.C. 1704(b)(3)), to conduct research and disseminate information. These agencies exercise this authority pursuant to delegation from the Secretary.

C. The Applicability of Technology to Other Government Programs and the Private Industrial Sector, Question 2

The large agencies which sponsor research and development in almost every field of science and engineering agree that a substantial potential exists for the secondary application of their technology. This view of technology holds it to be a basic resource for further exploitation. It should be noted that Federal agencies do a substantial amount of R. & D. directly for industrial use—mainly in medicine, natural resources, and agricultural utilization. There are many formal relationships for direct transfer (primary application) related to agency missions, for example, National Bureau of Standards services to industry. (See also USDA, p. 90, DHEW, p. 121, and DI, p. 117.)

As missions change and new public needs arise, specific interagency transfer arrangements are made; for example, NASA research on aircraft skidding on wet runways has led to liaison with the Bureau of Public Roads for application in highway safety.

The agency replies are hesitant in placing any quantitative value to industry on the results of their R. & D. in secondary applications. The lack of data, the long timelag for obvious effects and the complexity of industrial innovation are cited as reasons why no direct relationship can be stated. Selected replies on this subject (compiled from reports furnished by the agencies) are presented below.

1. NATIONAL AERONAUTICS AND SPACE AGENCY

The National Aeronautics and Space Administration conducts research, development, engineering, and evaluation in nearly every scientific and engineering discipline. Therefore, much of what is learned through the agency's programs has immediate relevance in other sectors of the economy. But—more importantly—the NASA technology utilization program has deliberately established mechanisms to communicate knowledge across disciplinary, industry, and regional lines, so that an innovation, discovery, and incremental advance in knowledge in one field can have immediate relevance in another field.

Mission oriented agencies, especially those whose missions are so broadly based and complex as those of NASA, generate a very large amount of new knowledge. But volume of knowledge alone is an insufficient basis on which to determine the need for special programs to transfer this knowledge from its many points of origin to its many more points of potential use. The size, complexity, and accessibility of the knowledge inventory available to an innovator establishes limits within which he must function; a sizable inventory allows for more combinations and permits more approaches than does a small one; the intelligibility and accessibility of the inventory determines to a very important extent its utility.

There are numerous indications that new technologies being created and nurtured with public funds, in support of public missions such as defense, aeronautics and space, and nuclear energy, have great value in secondary applications.

Much new knowledge has its most important real and potential impact in endeavors other than those in which it originated. A good example is the applicability of findings in fluid dynamics research and pump technology to the requirements of those concerned with improving and buffering the human cardiovascular system. Another example is the applicability of systems analysis and systems engineering concepts and techniques to urban problems.

A single innovation also, of course, can have relevance in a multiplicity of secondary applications. For example, Government-sponsored research and development has brought about a range of manipulators and other devices that dramatically extend human physical capabilities. While the devices themselves have secondary applicability, the underlying concepts and principles have far broader utility—because understanding them permits the development of analogs of the original devices for a multiplicity of purposes, such as improved prosthetic devices, material handling equipment, ocean engineering requirements, medical diagnostic tools, and numerous other uses.

Knowledge is seldom provincial. The critical point is the vital importance of building an information bank in such a way that a wide range of objectives can be defined and articulated in such a manner that a divergence of applications can feed from the same bit of information. Just as a given dollar from a conventional bank can be used for such diverse purposes as canals and cattle, so a given bit of knowledge, in combination with other bits of knowledge, has a large number of potential uses.

Technology, then, it seems, should be considered as a basic resource and policies to determine the means of its transferability should recognize its ubiquitous nature.

In a society structure that encourages increased specialization, traditional means of communicating no longer suffice. When new knowledge was generated in smaller amounts and fewer fields, the professioal journal provided an admirable means of communicating new knowledge. And when our industrial structure was less complex the trade magazine provided a channel for communication of comprehensive information within an industry. But specialization within disciplines and fragmentation of manufacturing activities have splintered those communication timbers. Where once one publication could cover a broad field, today 50 or more publications report on specific segments of that field. Not only has it become increasingly difficult to communicate across industry and disciplinary lines—it has become extremely difficult to communicate between fields of specialization within a single industry or discipline. And it is across such lines that new knowledge must flow if its optimum utility is to be obtained.

The applicability and value of NASA-generated technology—when viewed in the above light as bits of knowledge—to other Federal agencies and to the private sector has been demonstrated. Attachments B and C provide a few case examples of the use of NASA-derived technology for other purposes.

Another indication of relevance is the fact that more than 250 companies are now paying annual membership fees at the NASA-sponsored regional dissemination centers. This represents a substantial increase from the fewer than 100 companies paying membership fees 1 year ago. Further, experience to date suggests these companies—which range greatly in product lines, market orientations, sizes, and regions—have found NASA information relevant to their requirements because renewal rates have been exceeding 90 percent, and many companies have renewed their memberships for higher rates of service than asked for in their initial year of membership.

In cooperative programs with the Office of Law Enforcement Assistance (Justice Department) and Vocational Rehabilitation Administration (HEW), NASA technology is proving relevant to the missions of these agencies.

Another indication of relevance to industry requirements is the fact that NASA Tech Briefs are now generating industrial inquiries at a rate of approximately 1,000 inquiries per month.

A further indication is that trade, technical, business, and professional magazine editors—who must be attuned to industry's knowledge requirements—are presenting NASA innovations to their audiences at a record rate.

2. THE DEPARTMENT OF COMMERCE

With respect to the value of such technology, we think that it is indispensable. Essentially all new methods of determining standards, and many of the new instruments and techniques for weather observation and prediction, or for precision geodetic surveying are generated within our organization. Even though we obtain instruments and scientific and technical concepts from many outside sources, we still must develop many to accomplish our missions effectively.

The value of DOC technology to other agencies

Other Federal agencies depend upon NBS for essentially all of the technology of standardization. The services of NBS in this and other areas of competence are so valued by other agencies that they provide approximately one-half of its total operating funds.

Under Public Law 89–306, NBS has a central Federal responsibility to provide technical advice to all Federal users of automatic data processing systems.

With respect to the technology developed in ESSA, it appears that our primary transfer to other agencies is to their related programs in the observation and prediction of the atmosphere and the ocean, and in the earth sciences and surveying. We do not have a quantitative measure of the magnitude of this transfer, but we know of many specific instances, and we believe it is very substantial.

The value of DOC technology to industry

The private industrial sector relies heavily on NBS for standards and standards technology. Much of this transfer is accomplished through the Bureau's three-section Journal of Research and eight different series of nonperiodical publications, for which there are 3,000 to 6,000 subscribers, depending on the item, mostly from industry. Also, much of this is transferred by visits and personal contact. In particular, there are at the present time over 50 industrial associates from 21 different industrial organizations working at the Bureau on projects of mutual interest between the Bureau and industry.

In addition, the Bureau has a program of making available to industry many types of standard reference materials. Approximately 72,000 samples of such materials were purchased from the Bureau during the past year.

The NBS estimates that 5 percent of its professional effort is spent in consulting services to both industry and other Government agencies.

The NBS also operates the Clearinghouse for Federal Scientific and Technical Information, to be discussed later.

The activities of ESSA are unique in that there is very little related activity in the private sector of the R. & D. or developmental type, and to our knowledge, there has been little technology transfer in the form of instruments, methods, and equipment, but the technical data produced by ESSA has wide application in the private sector.

3. THE DEPARTMENT OF DEFENSE

Department of Defense research and development is undertaken on the basis that such effort is required to support the Defense mission. It is anticipated that the benefits obtained from technology derived in the performance of DOD research and development will exceed the cost when evaluated in relation to the Defense mission. To obtain a better understanding of the DOD research and development process, we have an on-going study to determine and analyze the development history of selected, recently developed military systems and devices. Based on the limited number of cases studied to date we have strong indications that over 90 percent of the technological contributions to systems under development stem from Defense funded research and development. We also find that science and technology funds deliberately invested and managed for defense purposes, though not necessarily for a specific end item, have been about one order of magnitude more efficient in producing useful contributions than the same amount of funds invested without specific concern for defense needs. Thus, we see that although technology "spinoff" into defense weapon systems from nondefense sectors exists, it is very small, and it is quite inadequate to produce the number of innovations needed to produce large increases in effectiveness of defense weapon systems.

The initial conclusions of this study (Project HINDSIGHT) support our belief that a Department of Defense investment in defense related science and technology has a large, though not necessarily immediate, payoff.

The nature of the Department of Defense's mission requires engagement in almost every scientific and technical area. Thus, we frequently can expect to engage in technological areas which are of interest to other Federal agencies. To assure that scientific and technical information resulting from DOD sponsored research and development is available to other Federal agencies, it is the policy of the Department of Defense to provide technical reports without charge to other Federal agencies and their contractors, subcontractors and grantees. In addition to the dissemination of technical reports, DOD makes available services of its 22 information analysis centers.

It is our judgment that some portion of the DOD developed technology is applicable and has value to other Federal agencies. As an indication of this value, 526 Government organizations outside of the Department of Defense are currently registered to receive Department of Defense technical reports on secondary distribution.

In assessing the worth of spinoff to industry, we recognize that the increasing degree of sophistication of defense technology has led to an increasing divergence between this technology and civilian technology. Thus, tangible spinoff; that is, the direct application of defense developed systems and devices to the private sector, has become of less importance. Correspondingly, intangible spinoff, that is, the transfer of scientific and technological information to commercial use, has become more important than tangible spinoff. Intangible spinoff is at best difficult to identify in the more obvious cases and is impossible to identify in total. Therefore, while we recognize that defense generated technology has some applicability and value to the private industrial sector, we cannot quantitatively ascertain the value.

In order to facilitate, the application of defense developed technology to the private industrial sector, it is the policy of the Department of Defense to make technical information resulting from its research and development program readily available within limitations imposed by security. This is accomplished by encouraging the presentation of scientific results in the technical literature and providing unclassified technical reports to the Clearinghouse for Scientific and Technical Information within the Department of Commerce where it is made readily available to the public.

4. THE ATOMIC ENERGY COMMISSION

The many and varied activities described in responding to question 3 have resulted in a considerable transfer of technology within the AEC, to other agencies and their contractors, and to universities and colleges, industry, and the general public. The transfers which are best known, understandably, are those that represent major, readily identifiable, discreet items such as clean rooms, civilian power reactors, uses of isotopes, nuclear energy for the desalination of water, zonal liquid centrifuges, or improved water purification processes. While these major items are important, of equal importance are the numerous, incremental technological advances which, in total, can be and have been of substantial benefit to our industrial progress and economic growth. A substantial body of such technology exists within the AEC family. Our ongoing program is planned to identify the existing technology and to make it available to all interested organizations and individuals.

While we are convinced that a substantial portion of this technology can be useful to industry, it is difficult to determine how valuable a technology transfer program is to industry. Some of the factors which make an evaluation difficult are:

1. The problem of obtaining useful data to determine which technology was transferred and how extensively it is being used.
2. The necessity to use a multifaceted approach since no single transfer mechanism has proven to be the most effective. This situation probably exists because each industry uses a certain set of mechanisms and the set used varies from industry to industry.
3. The technology transfer process is very complex and not fully understood. Additional study is required to determine whether a Government-sponsored program is effective, what is the cost to the Government and to industry, and what are the resulting benefits to society.

The success achieved in transferring knowledge in the agricultural field lends credence to the concept that technology can be transferred in the industrial field. However, it may be necessary to sustain a technology transfer program for some years before a meaningful evaluation of its worth can be made.

5. THE DEPARTMENT OF AGRICULTURE

The Department of Agriculture shares numerous areas of responsibility with other departments and agencies of the Federal Government, particularly as related to the development, conservation, and use of natural resources, the protection of our environment, and the relation of the Nation's food supply to the health and well-being of the population. This Department benefits from the knowledge developed through research in many other Federal laboratories. The technology developed in this Department finds wide applications in other agencies of the Government. Some examples are:

USDA-developed technology

Nature	*Other Federal user*
Techniques for removing radioactive materials from soils or minimizing their effects.	AEC.
Improved aerial chemical application techniques	FAA.
Flame resistant cotton fabrics	DOD.
Synthesis of dextran as a blood volume extender	DOD.
Penicillin culture techniques	DOD.
Improved packaging methods and materials	GSA and others.
New, improved, and more economical house construction methods and materials.	HUD.
Materials and techniques for revegetating roadside cuts	BPR.
Definition of minimum nutritional requirements and development of low-income diets.	HEW.
Strip mine restoration methods	BM.
Microclimatic data for environmental data analyses	ESSA.
Hydrologic data from experimental watersheds	GS.
Techniques for maintaining and improving wildlife habitats.	FWS.
New and improved methods for chemical analyses	FDA, PHS.
Techniques for minimizing or controlling environmental or biological factors affecting human health.	PHS.
Improved range management techniques	BR, BLM.
General agricultural practices	AID.

The joint planning of research is constantly being enhanced through increasing use of interagency planning committees, the science information exchange, and many other procedures for effective coordination of effort among agencies.

The advanced agriculture that enables us to have ample food and fiber of good quality as a part of the world's highest standard of living is an outstanding example of the application of technology. It has been estimated that to have produced our 1963 farm output by the technology of 1940 would have required inputs valued at $17 billion more than were actually required.

In addition to its historic association with farmers, the publicly supported agricultural research agencies, including both the U.S. Department of Agriculture and the State Agricultural Experiment Stations, have long enjoyed a close working relationship with the agribusiness and corporate sector of private industry. Many examples can be cited of working relationships and even sharing of scientists and research facilities among public and private research and development organizations. This has been accomplished without in anyway impairing the integrity of the public institutions. In most areas industry has been quick to seize on the new principles and processes resulting from public research. For example, it has been estimated that 109 commercialized achievements valued at more than $6,360 million have been adopted as the result of about $308,800,000 expended over time for research and development to foster the utilization of agricultural products.

Where applicable, public service patents have preserved the findings of public research for the benefit of all without danger of monopoly or favoritism in the private sector. The general public has been the general benefactor of effective relationships between this Department and the private sector. It is significant to note that industry provided some 55 percent of the estimated $850 million expended for agricultural research and development in fiscal year 1965.

6. THE DEPARTMENT OF THE INTERIOR

The technology resulting from Office of Coal Research research contracts is, we believe, valuable and implemental to this Department with its broad responsibilities for natural resources. Much of the research being done will prove valuable to other Federal agencies in seeking to obtain solutions to such problems as air and water pollution, and greater economics in fuel combustion techniques with consequent savings, expand byproduct use, etc.

The Federal Water Pollution Control Administration research and development effort has, as a primary objective, the development of technology which will solve indentifiable water pollution problems. Accordingly, there is full applicability. For example, a plant for the effective treatment of the water of Lake Tahoe, Calif., was designed and constructed on the basis of information generated under the advanced waste treatment program of this administration. By utilizing the advanced techniques of activated carbon adsorption and coagulation, the treatment plant is now able to provide the high quality effluent required to assure the preservation of Lake Tahoe as a scenic wonder. As a second example, the reclamation of sewage for use in two recreational lakes by the Santee County Water District of California, may be cited. Similar attempts at waste-water reuse are now underway in Tucson, Ariz. and elsewhere.

Within the concept of "technology transfer" which has been defined in the report of the National Commission of Technology, Automation, and Economic Progress, Volume 1, February 1966, page 104, as "using new technology for purposes other than the specific ones for which it was developed", it is our judgment that the technology derived by the Bonneville Power Administration in the development of high voltage and extra high voltage transmission systems using both AC and DC transmission with primary generation of hydro sources and the development of steam and nuclear generation is of great value not only to the Bonneville Power Administration but to other Federal agencies such as the Tennessee Valley Authority, the Bureau of Reclamation, the Federal Power Commission, as well as to other public and private industrial sectors engaged in generation and transmission of electrical energy.

(a) The technology developed in support of the Office of Saline Water's mission (i.e., to develop practicable, low-cost means for the large-scale production of water of a quality suitable for municipal, industrial, agricultural, and other beneficial consumptive uses from saline water) is directly applicable to the OSW mission and is of direct value in reaching the goals established for the program. It is through the development of new technology that the Office of Saline Water hopes to achieve its goal of low-cost desalted water for the various parts of the country and the world.

(b) The technology is also applicable and of value to the programs of several other Federal agencies as well as many State and local organizations. To mention only a few of the many Federal agencies that are deeply interested in the technology developed under our program, the following agencies are listed:

Federal Water Pollution Control Administration.
Bureau of Mines.
Bureau of Reclamation.
Office of Water Resources Research.
U.S. Geological Survey.
Atomic Energy Commission.
National Bureau of Standards.
Corps of Engineers.
U.S. Navy Bureau of Yards and Docks.

In addition, we have had many discussions with State and local organizations on common water problems in an attempt to determine whether the application of current desalting technology to their specific water problems was feasible.

(c) Regarding the private sector, it is the Office of Saline Water's mission to foster and promote the development of technology in the desalting field to the point where private industry can take the processes and technical data developed and then use their skills and talents to continue the refinement and development of these processes for the production of low-cost desalted water on a large scale. This is being accomplished by having the private sector (universities, nonprofit institutions and private industry) participate in the conduct of the research and development work through our contract and grant program, as well as disseminate the results of these scientific and engineering efforts conducted under the OSW Program to all interested and concerned parties.

(a) The value to the Department of the Interior of the technology and investigations performed by the Bureau of Mines is as follows:

(1) Provides timely and authoritative technical economic advice required by the Department and other Bureaus of the Department for analyzing and evaluating domestic and foreign mineral resources problems, in proposing new legislation or amendments to existing laws, and in making rules relating to mineral and mineral fuel matters, and health and safety in the minerals industry.

(2) Provides basic information on statistics and the mineral and mineral fuel resource base with appropriate analyses and interpretation.

(3) Keeps the Department and other Bureaus in the Department apprised of technological, scientific and research activities and accomplishments in the Federal and private sector.

(4) Provides high-level technical, scientific, engineering and economic analysis skills in the minerals and chemical engineering fields which are available to and utilized by the Assistant Secretary—Mineral Resources in discharging his duties with respect to the development and utilization of minerals and fuels, including defense minerals activities.

(b) The information and technology described in items (1) and (2) of part (a) above are also provided to other Federal agencies in a timely and authoritative manner through the medium of interagency reports, consultative services, cooperative studies, and through published reports and information.

(c) The Bureau's contributions to the private industrial sector are as follows:

Although the private industrial sector of the minerals industry has, in the past, benefited appreciably from Bureau of Mines research and development, and can be expected to continue to do so in the future, the advancement of industrial interests is an incidental effect rather than the primary objective of Bureau programs.