1987

TECHNOLOGY TRANSFER FROM FEDERAL LABORATORIES TO THE PRIVATE SECTOR

ISSUE PAPERS AND BIBLIOGRAPHY

Prepared for

U.S. Department of Commerce
Office of Federal Technology Management
Washington, D.C.

GULF SOUTH RESEARCH INSTITUTE
Baton Rouge, LA • New Orleans, LA • Washington, D.C.

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INTRODUCTION

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PURPOSE

Technology Transfer From Federal Laboratories to the Private Sector provides a set of instructional materials that can be used within Federal laboratories to assist in meeting Federally mandated responsibilities for technology transfer. Three sets of instructional materials were prepared for use by technology managers, scientists and engineers, and policy makers. These instructional materials are based on eight issue papers that address various aspects of technology transfer, including topics of particular interest in Federal laboratories such as the university experience in cooperative research and private sector operations and concerns. This document contains the issue papers, as well as an annotated bibliography.

ISSUE PAPERS

The issue papers provide a theoretical background for topics covered in the instructional materials. They represent a synthesis of relevant literature and incorporate the experiences of practitioners, including the project team members, other private sector firms, and university and Federal laboratory personnel. They are intended to serve as a permanent information source for the laboratories, providing background for making decisions regarding appropriate courses of action. They are appropriate for each of the three audiences, although it is expected that they will be particularly useful to ORTAs and laboratory managers, who must have a firm grasp of the issues in order to accomplish their transfer objectives.

The eight issue papers are:

Issue Paper I: Federal Policy and Technology Transfer Legislation

Issue Paper II: The Technology Transfer Process

Issue Paper III: Innovation and the Private Sector

Issue Paper IV: Cooperative Research and the Private Sector

Issue Paper V: Cooperative Research: The University Experience

Issue Paper VI:	Intellectual Property and Technology Transfer
Issue Paper VII:	Classification System for Technology
Issue Paper VIII:	Evaluating Technology for Transfer

The papers were prepared by project team members from Gulf South Research Institute (Baton Rouge, Louisiana); Gellman Research Associates, Inc. (Jenkintown, Pennsylvania); and Shackson Associates, Inc. (Ann Arbor, Michigan). Issue papers I, II, IV, and V were written by Jacques D. Bagur, Barbara E. Manner, and Ann S. Guissinger of Gulf South Research Institute. Issue papers III, VI, and VII were written by Aaron J. Gellman and Henry Hertzfeld of Gellman Research Associates, Inc., and Issue Paper VIII was written by Richard H. Shackson of Shackson Associates, Inc.

BIBLIOGRAPHY

Although the bibliography was initially developed to cover the topics addressed in the issue papers, it was expanded to cover additional topics addressed in the instructional materials. Thus, the bibliography is organized roughly in keeping with the topics addressed in the instructional materials for technology managers.

The topics covered by the bibliography are as follows:

1. Policy--innovation, science, and transfer policy
2. Technology--the nature of technology and the relationship between science and technology
3. Technology Transfer--general studies, transfer from Federal labs, and case studies
4. Actors and Mechanisms--general descriptions, specific actors and mechanisms, and practical approaches
5. Technological Innovation--innovation in the private sector, incremental innovation, and case studies
6. Technology Management--the management of technology and technology transfer
7. Cooperative Research and Conflict Issues--university and Federal laboratory cooperative research with the private sector and the university conflict issues emanating from cooperative research
8. Transfer Preparation--innovation awareness and classifying, evaluating, and managing technologies for transfer

9. Patenting and Marketing--intellectual property and the valuing, pricing, and marketing of technology.

Brief annotations are included with each citation indicating its importance or relevance to Federal laboratory technology transfer activities. The bibliography is not intended to be comprehensive, but represents a selection of the best literature for orienting Federal laboratory personnel to the factors that they must deal with in transfer activities. Many citations are to private sector experiences that provide parallels to Federal transfer activities or that must be taken into consideration in transfer to the private sector.

Issue Paper I

FEDERAL POLICY AND TECHNOLOGY TRANSFER LEGISLATION

Issue Paper I

FEDERAL POLICY AND TECHNOLOGY TRANSFER LEGISLATION

Gulf South Research Institute

Prior to 1980, little incentive and limited capacities existed for the aggressive management and transfer of technology from Federal laboratories to the private sector. Although the Federal laboratories are potentially a rich source of ideas, research capabilities, and technology that could be of great benefit to national economic growth, it has been difficult for the private sector to gain access to this vast array of technical resources. Beginning in 1980 with the Bayh-Dole and Stevenson-Wydler acts, Congress enacted a series of legislative measures designed to enhance the capacity of the laboratories to actively participate in the innovation process. For the first time, technology transfer to the private sector became a specific mission of the Federal laboratories. Each act gradually, but consistently, expanded transfer authorities toward including all the Federal laboratories.

By examining the Federal Technology Transfer Act of 1986, prior related legislation, and Executive Order 12591 (April 1987), it is clear that the results of Federal R&D efforts can legally be used for private benefit. Furthermore, Congress expects the laboratories to participate more actively in the innovation process and authorizes activities that are closer to moving a technology to market (i.e., patenting and licensing technologies for commercial applications) than are the more traditional forms of information transfer, such as publication.

The Federal legislation enacted between 1980 and 1986 and the 1987 Executive Order establish this policy for the laboratories by mandating technology transfer and by providing incentives and rewards to those who successfully transfer technology to the private sector. The legislation was intended to provide the laboratories with the tools and flexibility required to become proactive in technology management and transfer activities.

Some provisions of the recent legislation apply to all Federal laboratories[1], while some refer only to government-operated or nonprofit contractor-operated laboratories. Congress has not fully dealt with for-profit contractor-operated laboratories in the legislation.

LEGISLATIVE OVERVIEW

In the Stevenson-Wydler Act, Congress stated that "technology and industrial innovation are central to the economic, environmental, and social well-being of the citizens of the United States..." (Public Law 96-480, section 2), and that the Federal government's investment in the laboratories must contribute to U.S. industrial innovation. The rationale for technology transfer is that innovations serve to improve the standard of living by increasing public and private sector productivity, creating new industries and employment opportunities, improving public services, and enhancing the competitiveness of U.S. products in world markets. However, Congress recognizes that institutional and legislative barriers to the transfer of laboratory-developed technologies exist, and that it is necessary to improve the flow of the technologies developed in the Federal laboratories to the public and private sectors.

In the mid 1970s, some agencies (e.g., the National Institutes of Health, the National Science Foundation) began negotiating Institutional Patent Agreements with universities conducting R&D using Federal funds. Under these agreements, the universities were allowed to retain title to Federally funded technologies if they agreed to establish a system to manage them. Experience gained through these agreements served as the basis for the consensus that allowed passage of the Bayh-Dole Act.

The Stevenson-Wydler and Bayh-Dole acts, passed in 1980, began the emphasis on transferring technologies developed in the government's laboratories to organizations that could use them to develop commercial products, processes, and services. In the Stevenson-Wydler Act, technology transfer is considered an integral part of the laboratories' research and development functions, and mechanisms are created for facilitating the transfer of technologies developed in the laboratories.

The Bayh-Dole Act gives small business and nonprofit contractors the right to claim title to technologies developed under contract with Federal agencies. However, the Act contained an exception which allowed agencies to withhold this right from contractors operating Federal laboratories. Some agencies, particularly the Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA), used this exception in contracts with the operators of their laboratories, while other agencies did not use the exception. The Act also clarified authorities for Federal agencies to apply for U.S. and foreign patents, and for the first time, clearly authorized agencies to license their patents.

Despite the patenting and licensing provisions of the Bayh-Dole Act and the transfer mechanisms set up by Stevenson-Wydler, technologies were not being transferred effectively to the private sector. Agencies handled the patenting and licensing for their laboratories, and the lengthy process often discouraged companies. Laboratories were also hampered in working with the private sector, because many did not have the legal authority needed to enter into cooperative R&D agreements.

A Presidential Memorandum on Government Patent Policy (issued on February 18, 1983) directed that, to the extent permitted by law, agencies should allow all contractors to claim rights to technologies developed under a Federally funded contract, grant, or cooperative research agreement. This Memorandum extended the rights given to small business and nonprofit contractors in the Bayh-Dole Act to all contractors; however, the Memorandum's impact on contractor-operated laboratories was limited by conflicting laws.

The 1983 Federal Laboratory Review Panel's report (also known as the Packard Report) states that more collaboration between Federal, private, and university laboratories is in the national interest. The Panel concluded that increased interaction between industry and the laboratories could occur and that the laboratories could be better attuned to industry's needs without interfering with the laboratories' R&D missions. The report also urges improved access to the laboratories' facilities, personnel, and technologies.

In the Trademark Clarification Act of 1984 (Title V), Congress attempted to remove some of the remaining barriers to transfer. This Act, which amends Bayh-Dole, limits the exception that allowed agencies to continue to own technologies developed at nonprofit contractor-operated laboratories. Once implemented in the laboratory operating contracts, this amendment will allow nonprofit laboratory operators to own technologies that are not related to weapons systems or naval nuclear propulsion. The laboratories will then be in a position to protect technology and license it directly to interested parties without going through the funding agency. The ability to retain royalty income (up to a limit) is provided as an incentive to laboratory management and personnel. The developing laboratory must share royalties with the inventor and use the remaining income for support of research, development, and education in the laboratory.

The Trademark Clarification Act eliminated some of the barriers to transfer for nonprofit contractor-operated laboratories; however, legislation allowing all contractors to retain ownership of technologies made at their laboratories failed to pass. Consequently, technologies developed at for-profit contractor-operated laboratories were still owned by the Federal government, unless the funding agency waived ownership rights to the laboratory.

Under the Federal Technology Transfer Act of 1986 (Public Law 99-502), all laboratories are expected to improve transfer activities, focusing on firms that will commercialize laboratory technologies. To accomplish this objective, Congress expanded authorities of the government-operated laboratories. The 1986 Act, amending Stevenson-Wydler, allows the agencies to turn over responsibility for licensing technologies to the originating laboratory. The agencies may also allow their laboratories to enter into cooperative R&D agreements without agency approval.

For the first time, government-operated laboratory personnel were guaranteed incentives for participation in technology transfer efforts. Agencies are required to share royalty income with the inventor(s) and to provide cash awards to personnel for outstanding scientific and technological work and exemplary technology transfer activities.

Concerns about professional advancement were addressed in Public Law 99-502 (section 10), which states that "...technology transfer...is a responsibility of each laboratory science and engineering professional ..." and that:

> Each laboratory director shall ensure that efforts to transfer technology are considered positively in laboratory job descriptions, employee promotion policies, and evaluation of the job performance of scientists and engineers in the laboratory.

The 1987 Executive Order, "Facilitating Access to Science and Technology," gives the 1983 Presidential Memorandum on Government Patent Policy the force of law. The Order requires the agencies to delegate the authority to enter into licensing and cooperative agreements to their government-operated laboratories, to the extent permitted by law. It also requires the agencies to allow all contractors the same rights with respect to technologies that small and nonprofit contractors are allowed by law, to the degree permitted by law.

There is some disagreement regarding the status of the Department of Energy for-profit contractor-operated laboratories under the Executive Order. The need for legislation to clarify the disagreement is under discussion. Consequently, for-profit contractor-operated laboratories will not be discussed further in this paper.

DUTIES AND RESPONSIBILITIES OF ORTAS

The Offices of Research and Technology Applications (ORTAs) were established at the Federal laboratories by the Stevenson-Wydler Act. In 1986, their technology transfer duties were expanded. Specific technology transfer duties and responsibilities are outlined for the ORTAs, and the National Technical Information Service (NTIS), Federal Laboratory Consortium for Technology Transfer (FLC), and Department of Commerce (DOC) are authorized to provide support functions.

The legislation provides ORTAs with staff and funding to assure that laboratory technologies are effectively commercialized. Staffing levels will be determined by each laboratory and its funding agency, although one full-time equivalent ORTA position is required at each laboratory with 200 or more full-time positions. House Report 99-415 indicates that Congress expects the laboratories that are not required to have a full-time equivalent professional to have one person devote "substantial efforts" to technology transfer efforts.

In 1986, Congress elevated the ORTA function to the laboratory management level. This change is partly a result of Congress emphasizing the importance of this function and partly because successful technology transfer requires active efforts by personnel who are familiar with technical aspects of the R&D work and have decision-making authority. The House Report (99-415) accompanying the 1986 legislation states that the ORTA:

> ...should identify technology and expertise within the laboratories, should identify technical needs and potential applications in the public and private sectors, and should work with local, regional, and national groups, including the Federal Laboratory Consortium (FLC). Although technical information activities, such as technical report preparation and distribution, library, and other information services, contribute to some technology transfer projects, these activities alone are not considered to satisfy the intent of this Act.

Each ORTA is responsible for identifying technologies within the laboratory that may have potential commercial applications and preparing assessments of those technologies. According to the House Report, the application assessments are intended:

> ...as part of an active effort to transfer laboratory technology and not as a lengthy bureaucratic effort to create a reference document. They can be targeted to specific groups of likely users and should be short and direct enough to be relevant to busy professionals who, if interested, can come back to the laboratory for more information.

The ORTAs are expected to produce and disseminate information on Federally owned or originated technologies to government and industry. However, agencies that have existing organizations engaged principally in technology transfer activities may choose to continue using these organizations. Other ORTA functions include cooperating with and assisting NTIS, the Federal Laboratory Consortium for Technology Transfer (FLC), and other organizations to link the R&D resources of the laboratories and the Federal government to potential users.

Funding for technology management and transfer activities is provided through each agency's R&D budget. At least 0.5 percent of an agency's budget must be made available to support the technology transfer function at the agency and its laboratories. An agency may waive this requirement only if the reasons for the waiver and alternate plans for conducting the technology transfer activities are submitted to Congress with the President's budget.

The Roles of NTIS and the FLC

In order to better support the ORTAs, the 1986 Act both changed and enhanced NTIS and the FLC. The FLC became a formal organization with funding and administrative support. The Center for the Utilization of Federal Technology (CUFT), created in 1980 as an independent entity, has in practice functioned well as a part of NTIS. The 1986 amendment abolishes CUFT as a separate entity and splits its functions between NTIS and the FLC. CUFT's operations will continue within NTIS.

The NTIS and the FLC serve as facilitators, assisting business and industry, state and local governments, and not-for-profit organizations (including universities) in obtaining information about laboratory research and development activities. The NTIS is responsible for handling those requests for which published information is relevant. The FLC, which serves as a networking system between the Federal laboratories, refers all other requests to the appropriate Federal laboratories and agencies.

The FLC also serves an educational function. It is responsible for developing and administering training courses and materials designed to improve invention awareness among Federal laboratory employees. The FLC may also support technology transfer efforts by providing assistance to the laboratories and agencies upon request. However, the laboratories and agencies must transfer their technologies directly to users. The FLC is not intended to function as an intermediary.

To fund FLC operations, each agency must transfer 0.005 percent of the portion of its R&D budget allocated to its laboratories to the National Bureau of Standards (NBS). Federal agencies and the directors of Federal laboratories may provide additional support for FLC operations at their discretion.

Assistance from the Department of Commerce

The DOC may assist laboratories by providing methods to evaluate the commercial potential of technologies and information concerning options for commercialization. For laboratories establishing cooperative R&D efforts, the DOC may provide information, advice, and assistance, upon request.

AUTHORITIES GIVEN TO LABORATORIES

When implemented, the legislative measures passed since 1980 and Executive Order 12591 will allow the laboratories to exercise more control over their technologies than ever before. Rights are granted to:

- Retain ownership of technologies;
- Enter into cooperative R&D agreements;
- Patent technologies;
- License and assign technologies;
- Use royalties for laboratory purposes; and
- Initiate personnel exchanges.

Nearly all laboratories are expected to be authorized to negotiate licensing agreements and participate in personnel exchanges, and all are required to share royalties with the inventor (Figure 1). However, distinctions are made between the types of laboratories (e.g., government-operated, contractor-operated) with respect to rights to retain title to technologies, and authorization to enter into cooperative R&D agreements.

Right to Retain Title to Inventions

Traditionally, the Federal government has automatically maintained the rights to all technologies developed in the Federal laboratories. In an effort to decentralize technology transfer activities, Congress first gave small businesses and nonprofit organizations the right to

Figure 1. AN OVERVIEW OF AUTHORITIES GRANTED TO FEDERAL LABORATORIES

Legislative Authorities and Actions	Government-Operated Laboratories	Nonprofit Contractor-Operated Laboratories	Agencies
Transfer Federally owned and originated technology to government and private sectors	SW,FTT	SW	SW,FTT
Establishes and funds ORTAs to manage technologies at the laboratories	SW,FTT	SW,FTT	FTT
Nonprofit contractors may claim title to most inventions	BD	BD,TC	BD,TC
Inventors may claim title to inventions if contractor and government do not	FTT	BD,TC	BD,FTT
Apply for patents	BD,FTT	BD,TC	BD
Negotiate exclusive, partially exclusive, or non-exclusive licenses	FTT	BD,TC	BD
. Licensing may be done at the laboratory where the invention was made	FTT	TC	
. Products for sale in the U.S. must be manufactured substantially in the U.S.	FTT	BD,TC	BD
. Licenses may be royalty free or for royalties	FTT	BD,TC	BD
. Preference should be given to small business (with some exceptions)	FTT	TC	BD,TC
Administer royalties	FTT	BD,TC	FTT
. Share royalties with inventors	FTT	BD,TC	BD
. Use remaining royalties for activities related to licensing and education	FTT	TC	
Enter into cooperative R&D agreements	FTT,EO		FTT,EO
Exchange personnel among academia, industry, and Federal laboratories	SW	SW	

NOTE: BD = Bayh-Dole Act (1980), Public Law 96-517
SW = Stevenson-Wydler Act (1980), Public Law 96-480
TC = Trademark Clarification Act (1984), Public Law 98-620
FTT = Federal Technology Transfer Act (1986), Public Law 99-502
EO = Executive Order No. 12591, "Facilitating Access to Science and Technology (1987)

own technologies developed under contract, and thereby facilitate commercialization (Bayh-Dole Act, 1980). The second legislative step (1984) was to give most nonprofit contractors operating Federal laboratories these same rights. (Only technologies developed as a part of naval nuclear propulsion or weapons programs cannot be claimed by nonprofit contractors operating laboratories.) The recent Executive Order (1987) extends the right to claim title to technologies to all contractors, to the degree permitted by law.

Technologies developed by laboratory personnel at the government-operated laboratories are still owned by the government, but under Public Law 99-502 and Executive Order 12591, management of the technologies is expected to be delegated to the laboratories.

If a nonprofit or small business contractor does not choose to claim title to a technology its employees developed, the inventor may, with approval of the government, claim rights to the technology. Similarly, if the government does not choose to retain title to a technology developed at a government-operated laboratory, the inventor may claim title.

Nonprofit and small business contractors must follow specific guidelines for disclosure to the government and claiming title to technologies. If these guidelines are violated, the government may retain title to the particular technology. In addition, limits on the right to retain title are imposed in situations involving foreign contractors and national security matters.

It should be stressed that when the contractor or the inventor retains rights to a technology, the government is always granted the right of use for its own purposes on a nonexclusive, royalty-free basis.

Cooperative Research and Development Agreements

Congressional testimony prior to the passage of the Federal Technology Transfer Act of 1986 revealed that the authority to enter into cooperative R&D agreements varied among the agencies. For example, NASA has engaged in cooperative R&D for many years. Some agencies have no statutory authority for entering into these types of agreements, while others require a lengthy and difficult process that discourages many laboratories and industries from requesting approval.

Provisions in the 1986 Act are intended to enable all government-operated laboratories to enter into cooperative R&D agreements with private companies, universities, and state and local governments. Under this Act, if given the authority by their governing agency, government-operated laboratories may enter into a variety of cooperative agreements and may (Public Law 99-502 section 11):

> ...accept, retain, and use funds, personnel, services, and property from collaborating parties and provide personnel, services, and property to collaborating parties....

These agreements must be negotiated and may contain provisions that grant licenses, assignments, or options to technologies to the collaborating party. The laboratory may also waive in advance any ownership rights to technologies made under the cooperative agreement, thus allowing the collaborating party to own any technologies developed. However, the Federal government always retains the right to use the technology for its own purposes on a royalty-free basis.

In entering into cooperative agreements, the laboratories are required to give special consideration to small businesses and to firms located in the United States that agree that products embodying technologies developed under these agreements will be manufactured mainly in the United States.

Agencies are required to review standards of conduct relating to conflict of interest issues. The agency must identify any potential conflicts of interest that cannot be resolved based on current statutes and propose changes to its authorizing Congressional committees.

The Executive Order of April 1987 requires the agencies to give the government-operated laboratories the authority to enter into cooperative R&D agreements. The government-operated laboratories are the only Federal laboratories given clear authority to enter into these agreements; however, the Executive Order urges the agencies to encourage and facilitate collaboration at all Federal laboratories. Congress has given the laboratories the authority to enter into cooperative agreements in an effort to avoid long delays in obtaining approval from agencies.

Cooperative Research Centers

Cooperative research centers are mechanisms to encourage industry, universities, and Federal laboratories to conduct research in areas that are of economic or strategic importance, but in which any single firm has little incentive to invest. The Federal Technology Transfer Act of 1986 authorizes the Department of Commerce to assist the Federal laboratories to develop cooperative research centers and other types of joint research efforts that stimulate innovation and encourage technology transfer.

The 1987 Executive Order establishes a "Technology Share Program." Under this program, five Federal agencies will select laboratories to identify research areas in which they have special expertise or facilities that are important to long-term national economic competitiveness. A research consortium, involving three or more U.S. companies, will be established to conduct research in a selected area. The laboratory is authorized to use facilities, personnel, and financial resources in support of the consortium. Financial support from a laboratory is limited to 25 percent of the consortium's total budget and cannot exceed $5 million per year.

Patenting

The technology transfer legislation passed since 1980 provides only minimal guidance on patents. Bayh-Dole (1980) authorizes the agencies, organizational structures that transfer Federally owned technologies for the agencies (such as NTIS), or laboratories claiming rights to technologies to obtain patents. It also specifies that information on technologies may be withheld for a reasonable period until a patent application is filed.

Nonprofit contractors who operate Federal laboratories and choose to retain rights to a technology have one year from their election to own a technology (or, if earlier, one year from publication or use of the technology) to apply for a U.S. patent. The contractor must also file foreign patent applications (if any) within a "reasonable period of time." The Federal government may claim title to the technology if the contractor does not file the U.S. or foreign patent applications within the appropriate time periods.

Licensing

The Bayh-Dole and Trademark Clarification acts contain provisions related to the licensing of technologies owned by the Federal government and by nonprofit and small business contractors. The acts authorize the agencies and contractors to grant exclusive, nonexclusive, and partially exclusive licenses[3].

Exclusive licensing of technologies developed at the Federal laboratories is relatively new. Prior to 1980, the prevailing viewpoint was that all government funded technologies should be available to everyone, and that nonexclusive licensing was the best way to accomplish this objective. With the authority to negotiate exclusive licenses (granted in 1980), Congress acknowledged that there are many cases where technologies would not be commercialized because companies could not afford the development and marketing costs if some protection against direct competition was not assured. Although it is still more difficult to grant exclusive and partially exclusive licenses, rather than nonexclusive licenses, many exclusive licenses have been granted.

It should be clearly understood that in granting exclusive licenses, the government retains royalty-free right of use. This is to ensure that it does not have to pay royalties on technologies that are developed with Federal funds.

Licensing Procedures

Regulations for licensing of government-owned and, to some degree, contractor-owned technologies have been developed. As the recent legislation is implemented, the originating laboratories will be increasingly responsible for licensing their own technologies.

Government-Owned Technologies

The 1987 Executive Order requires each agency to permit its government-operated laboratories to negotiate licensing agreements for technologies originating at those laboratories, as well as any other technologies developed by their employees that may be assigned to the government. These licensing agreements must be negotiated under specific guidelines.[4] Both the agencies and laboratories may allow organizations established to transfer Federally owned or originated technologies (such as NTIS) to negotiate the licenses.

Agencies, designated organizations, and the laboratories are allowed to negotiate and grant licenses for any Federally owned intellectual property that is protected by patents, patent applications, or other forms of protection. The following restrictions and requirements are placed on licenses:

- The applicant for a license must submit a satisfactory development or marketing plan (or both) to the party (agency, designated organization, or laboratory) negotiating the license. This plan must include information on the applicant's ability to accomplish the plan(s);
- The licensee must carry out the development and/or marketing plan within a specified time period;
- The licensee must report periodically on the commercialization or efforts to commercialize the licensed technology;
- Licenses will usually be granted only to applicants who agree that products made using the technology will be manufactured substantially in the United States;
- Licenses may be granted for use according to geographical areas and/or fields of use;
- Licenses cannot be assigned to another party without the approval of the original negotiating entity;
- Sublicenses may be granted with approval of the original negotiating entity;
- The license may be terminated under certain conditions (e.g., if the proposed development or marketing schedules have not been met and the licensee cannot show that appropriate steps are being taken to commercialize the technology);
- The government may grant the licensee the right to protect the license from infringement.

Under current law, exclusive and partially exclusive licenses may be granted when: (1) the interests of the government and the public will be best served by an individual applicant as determined by the firm's plans and ability to bring the technology to practical application; (2) the desired practical application has not occurred and is not likely under a nonexclusive license; or (3) the financial investment necessary to undertake development is such that development under a nonexclusive license is not likely to occur.

There is a three month waiting period following the notice of availability published in the Federal Register, and small businesses submitting acceptable development plans receive preference for exclusive licenses.

Nonprofit Contractor-Owned Technologies

The regulations governing licensing by nonprofit contractors are less restrictive than those concerning Federally owned technologies. The Trademark Clarification Act of 1984 authorizes the laboratories to license their own technologies. Licensing regulations governing nonprofit contractor-owned technologies contain the following provisions:

- Laboratories are expected to give preference to small business licensees, unless large firms supported the research leading to the development of the technology.
- A Federal agency cannot require the licensing of contractor-owned technologies to a third party unless a written justification has been approved by the head of the agency. The requirement to license a third party can be approved only if it is considered necessary to achieve commercialization.
- To obtain an exclusive license to use or sell laboratory technologies in the United States, an applicant must agree to manufacture the products primarily in the United States. The Federal agency may waive this requirement if the contractor can show that domestic manufacture is not commercially feasible or that reasonable efforts were made to grant licenses on similar terms to licensees that would manufacture primarily in the United States.

- The funding agency maintains march-in rights for technologies. This means that the agency has the right (in certain cases) to require the contractor, an assignee, or an exclusive licensee to grant a nonexclusive, partially exclusive, or exclusive license to a responsible applicant or applicants. The agency may issue the license if the contractor, assignee, or exclusive licensee refuses to comply. The conditions under which the Federal agency may take such steps include the case where the contractor or assignee has not attempted and is not expected within a reasonable time to attempt to achieve practical application of the technology; if health and safety needs are not being satisfied; or when requirements for manufacturing substantially in the United States have not been met, or waived.

Personnel Exchanges

The Stevenson-Wydler Act encourages personnel exchanges among universities, industry, and the Federal laboratories. In addition, the 1986 amendment allows employees and former employees of government-operated laboratories to work with firms to commercialize laboratory technologies, if agency standards of conduct are met.

Incentives and Rewards for Transfer

The technology transfer legislation provides incentives and awards to encourage technology transfer activities at the government-operated and non-profit contractor-operated laboratories. The National Technology Medal is the only mandated incentive that applies to the for-profit contractor-operated laboratories. Personnel at all laboratories are eligible for the Medal. It is periodically awarded by the President to individuals or companies that have made "...outstanding contributions to the promotion of technology...for the improvement of the economic, environmental, or social well-being of the United States..." (Public Law 99-502, section 15).

Government-Operated Laboratories

Royalties and cash awards are the financial incentives provided to government-operated laboratories and employees by the legislation.

Royalties

It is the governing agency's responsibility to distribute royalties or other income received from the licenses. Inventors receive at least 15 percent of the royalties (or other income) from a technology, if the inventor was employed by the agency when the technology was developed. The agencies are authorized to develop other royalty sharing provisions, but apparently very few are considering an alternative program.

Uses of Royalty Income

The agency must distribute royalty payments to inventors, and transfer the remaining royalties to the laboratories, with the majority share going to the laboratory where the technology was developed. After receiving royalty income, the laboratory has through the next fiscal year to obligate the revenues before they revert to the U.S. Treasury.

Royalty income may be used to cover administrative and licensing expenses, "...including the fees or other costs for the services of other agencies, persons, or organizations for invention management and licensing services..." (Public Law 99-502, section 13). Any remaining funds must be used:

> ...to reward scientific, engineering, and technical employees of the laboratory; ...to further scientific exchange among the government-operated laboratories of the agency; or ... for education and training of employees consistent with the research and development mission and objectives of the agency, and for other activities that increase the licensing potential...of the Government-operated laboratories...

Royalty payments to employees do not affect regular compensation or awards, and payments continue after leaving the laboratory or agency. There is a $100,000 annual limit per person, unless the President approves a larger award.

Cash Awards

Any Federal agency with annual R&D expenditures totalling more than $50 million at all of its government-operated laboratories must develop and implement a cash awards program. These awards will be used to reward personnel for outstanding work that leads to commercialization of technologies or makes a significant contribution to laboratory mission responsibilities.

Nonprofit Contractor-Operated Laboratories

Contractors are required to share royalties with the inventor. Royalty income received by the laboratory should also be used to cover patenting costs, licensing costs, and other associated administrative expenses. Any remaining funds must be used for:

- Research and development related to the laboratory's mission;
- Education of laboratory personnel; and
- Activities that increase the licensing potential of laboratory technologies.

Reporting Requirements

Each agency must prepare an annual report for Congress (submitted with the agency's annual budget) on the technology transfer activities of its laboratories. Royalties and other income as well as expenditures (including inventor awards and royalty payments) must be reported to appropriate Congressional committees.

Every two years, the Secretary of Commerce must report to the President and Congress on how the agencies have used the authorities granted in Public Law 99-502.

By April 10, 1988, the Director of the Office of Science and Technology Policy is instructed to convene an interagency task force to report to the President on the progress of technology transfer from the Federal laboratories, identify any problems, and "identify and disseminate creative approaches to technology transfer from Federal laboratories." (Executive Order 12591)

CONCLUSION

Technology transfer legislation passed since 1980 and the 1987 Executive Order make it clear that Congress and the President intend for the Federal laboratories to become more active in moving technologies into the private sector and in working with the private sector to solve technical problems in areas where the laboratories have expertise. In an effort to facilitate transfer, Congress has decentralized administrative functions by authorizing the laboratories to handle their own licensing activities and to enter into cooperative R&D agreements. Recognizing that the active participation of laboratory personnel is a critical factor in successful transfer, personnel exchanges between Federal laboratories, industry, and universities are allowed and encouraged. The laws and Executive Order also provide financial incentives by requiring royalty-sharing with the inventor(s) and cash awards at the government-operated laboratories.

FOOTNOTES

[1] A Federal laboratory, as defined in the Stevenson-Wydler Act, is any laboratory, Federally funded research and development center, or any cooperative research center established under the Act that is owned, leased, or used, and funded by the Federal government. They may be operated by the government or by a contractor.

[2] Additional authorities are provided in the Interim Final Regulations issued in the Federal Register on Monday, July 14, 1986 (Vol. 51, No. 134).

[3] Partially exclusive licenses may be issued to more than one company or individual, but not to any company or individual desiring a license (a nonexclusive license).

[4] Section 207 of title 35, United States Code, and the regulations promulgated under section 208 of title 35, published in the Federal Register on March 12, 1985 (Vol. 50, No. 48).

Issue Paper II

THE TECHNOLOGY TRANSFER PROCESS

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Gulf South Research Institute

This paper deals with technology transfer, placing special emphasis on the implications for Federal laboratories. It discusses the nature of technology and the innovation process because these are integral to an understanding of transfer processes. These subjects are complex and the understanding of them is evolving. As a consequence, the paper does not state a thesis and then provide supporting evidence. Rather, it is an issue paper that looks at the subjects discussed from various perspectives, engages the reader in questioning about these subjects, and, it is hoped, provides the reader a greater appreciation of transfer processes in the absence of definitive conclusions.

DEFINITIONAL PROBLEMS

The term "technology transfer" is used to cover a wide range of phenomena. Much of the literature is concerned with transfer between nations. Other significant portions address transfer from:

1. The public sector to the private sector (e.g., from a university to a company)
2. The public sector to the public sector (e.g., from a Federal laboratory to a municipal government)
3. The private sector to the private sector (e.g., from one company to another through licensing)
4. The private sector to the public sector (e.g., from an industrial contractor to its sponsoring Federal agency)

What is the commonality that enables such diverse phenomena to be included under the term "technology transfer?" In other words, how should "technology transfer" be defined? Can we find a definition that would explain why many Federal laboratories consider all of their efforts to be technology transfer and why large companies speak of technology transfer when technologies do not move smoothly from one operational division to another?

The best places for finding an adequate definition for any term are from:

1. The person who coined the term (why was it necessary to introduce a new term and what was to be conveyed through it)
2. The community of practitioners and analysts (what do those who engage in or study technology transfer think that they are dealing with).

Origins

The term "technology transfer" was coined by John Welles in a 1963 Denver Research Institute report on The Commercial Application of Missile/Space Technology. DRI had been commissioned to identify the commercial applications of space research, which at the time were being called "byproducts."

DRI found that the byproduct terminology was misleading, since it implied that something was ready to go to market and that transfer was a simple matter. Most importantly, it suggested that industry was interested in the discrete objects (or artifacts) produced in the space program that could be applied as commercial products. DRI found some examples of "new product" transfer, but they were fifth in importance, and the artifacts were overengineered, had no immediate commercial potentials, and needed to be unravelled to reach a technological base from which commercial applications could be developed.

DRI also found that the bulk of transfer occurred through: (1) stimulation of basic and applied research; (2) new or improved processes and techniques; (3) product improvement (refinements to previously existing commercial products used in the space program and improvements to commercial products as a result of manufacturing, process control, and quality control techniques developed in the space program); and (4) materials and equipment availability. Subsequent empirical studies, such as DRI's 1972 report on Mission-Oriented R&D and the Advancement of Technology: The Impact of NASA Contributions, have reached substantially the same conclusion.

DRI realized that these additional categories were forms of technology and that even in the case of the "new products" category, what was used by industry was not the space "product" but its technological base. The term "technology transfer" was coined to avoid the misleading implications of the term "byproduct transfer," since it was technology (in various forms) that was being transferred rather than products.

The five different categories of transfer should have given rise to an expanded concept of technology and different types of transfer strategies to address the different types of technology that were being transferred. However, apart from various articles by the DRI project team, the initial empirically based insights did not become topical in the technology transfer literature; and, as a consequence, the term has ironically come full circle, with "technology transfer" understood by the public as equivalent to what was originally called "byproduct transfer."

Definitions

Since the time of the 1963 DRI report, a multitude of different definitions of technology transfer have been presented by practitioners and analysts. A random selection will serve as a basis for discussion:

1. The secondary application of technology developed for a particular mission or purpose to fill different needs in another environment.
2. A purposive, conscious effort to move technical devices, materials, methods, and/or information from the point of discovery or development to new users.
3. The use of knowledge to serve a purpose other than the one for which the R&D was undertaken.
4. The application of technology to a new use or user.
5. A process whereby technical information originating in one institutional setting is adapted for use in another institutional setting.
6. The utilization of an existing technique in an instance where it has not previously been used.
7. The process by which a technology is applied to a purpose other than the one for which it was originally intended.
8. Putting technology into a different context.

Although many exceptions have been and can be cited with respect to each of these definitions, it is not our intention to quarrel with any of them, particularly since many have been developed for specific purposes--either to emphasize some quality of technology transfer or to provide a definition that would fit a particular institutional setting.

Rather, what needs to be pointed out is that there is no unanimity of definition among practitioners and analysts.

Impressions

Assuming that these definitions are representative, what can we learn from them about the current state of knowledge concerning technology transfer? Inspection of the definitions reveals the following:

1. The term "technology" is indefinite (characterized variously as knowledge, technique, information, devices, and so on). Given such diversity, it is understandable why some commentators have chosen to incorporate the word "technology" into their definitions without attempting to establish a particular meaning.
2. The definitions place emphasis on two different aspects of technology transfer. Some stress that technology transfer is an activity (purposeful human action), others that it is an outcome (the fact that something has been transferred). Clearly, technology transfer should include both senses, since it is an activity that intends an outcome.
3. Although there is much disagreement on the nature of technology, most definitions do not make the mistake commonly made by laymen, who equate technology with artifacts (i.e., objects). Objects are generally not transferred in the transfer process, but rather some form of knowledge, of which artifacts are the physical embodiment. Exceptions to this generalization would include cases of international technology transfer in which artifacts and collections of artifacts (e.g., a manufacturing plant) are transferred; but even in these cases, knowledge (usually in the form of personnel) generally accompanies the artifacts so that they can be operated or modified to suit local conditions.
4. Most of the definitions suggest that what is transferred (or is to be transferred) is ready for use by the receiving organization or environment. A technical assistance telephone conversation would be an example, because the information would be usable in the form that it was transmitted. However, when we enter the realm of artifactual possibilities (e.g., when a technological idea has not yet been developed into a prototype), the need for developmental work is extensive. A similar situation exists at the opposite end of the development spectrum, when an artifact has already been produced (e.g., as the result of mission-oriented work in a Federal laboratory). Generally, the artifact as it exists is of little use. The receiver must use the technological form underlying the artifact to fashion something quite different that will be acceptable in the marketplace.
5. A closely related issue is that most of the definitions appear to preclude developmental work in the transfer process

itself; that is, preparation of a technology to increase its transferability is not assumed to be integral to the transfer process. This is not surprising, given the fact that the definitions do not emphasize development work in general. However, it is surprising given the technology transfer literature's strong emphasis on the need to identify the interests of potential users and to include such users early on in the development process.

6. The definitions strongly and rightly suggest that technology transfer is generally a transaction between organizations. However, they are unclear on the source of initiative and seem to preclude the possibility of joint management of a technology as it is being developed. Technology, according to the definitions, appears to be fully in the hands of one organization at one point in time and then in another at another point in time, with no managerial overlap.

7. Lack of clarity about the nature of technology combined with a strong emphasis on institutional relationships leads to the suggestion that what is transferred is somehow lost by the transferring institution. Indeed, the term "technology transfer" itself strongly suggests that something has been conveyed from one place to another, with a turning over of the technology by the originating institution. In most transfer efforts, however, nothing is lost by the originating institution other than time; and when value is transferred (e.g., through licensing), the value of the technology to the originating institution is increased.

8. Many definitions use the word "process" in connection with technology transfer. However, since the dimensions of the process are not identified and transfer is conceived of as a handoff, the transfer "process" automatically assumes the character of an event, rather than the lengthly and complex interactions that often transpire.

9. All of the definitions are strong on purpose. Technology transfer is an activity that is done for the sake of an end, which is generally referred to as use (a new use or a new user). However, no overall context for the transfer activity is indicated.

The weaknesses of such definitions can be summarized as follows:

1. The nature of technology is unclear.
2. The technology to be transferred appears ready for use.
3. Developmental work is not included as a transfer component.
4. Joint management of technology is not envisioned as a transfer strategy.
5. The relative role of actors in the transfer is unclear.

6. The originating institution appears to give up something of importance.

7. The dimensions of the process are unclear.

8. The context of the process is unclear.

In the expositions accompanying such definitions, some of these weaknesses are at least partly overcome; but in general, there is widespread dissatisfaction among practitioners and analysts concerning their own efforts to clarify the nature of technology transfer. The analytic literature, though rich in detail, does not convey an impression of the nature of technology transfer that is much different from that of the layman.

Images

The prevailing image is one of "getting it off the shelf," as if technologies were like commodities in a retail store. The store advertises its wares, the potential buyer comes in to shop, the salesman picks the selected items off the shelf, and the purchaser leaves with something ready to use.

Problems inherent in this image are exacerbated by models of technology transfer that present the process as an interaction between two elements, variously designated as source-user, donor-recipient, transferrer-transferee, and developer-implementor, with an arrow between the two pointing to the second element and ostensibly representing the transfer process. The problem with such models is not so much that they are wrong as misleading, and the image they convey cannot be corrected through a discursive clarification.

Obviously, for transfer to take place, something must be transmitted from one institution to another; it is the directional arrow and the terms that prejudice the models. Let us examine a few cases:

1. A company sees a product opportunity in work being conducted by a public institution. The institution does not see the opportunity, so the creative act that transforms the technical knowledge into a potential product is supplied by the company. Nevertheless, according to the model, the institution is the source and the company is the user.

2. A company establishes a relationship with a public institution to develop a technological possibility to

prototype stage. Most of the work is done in the company laboratory, with participation by an institutional scientist. Nevertheless, the institution is the donor and the company is the recipient.

3. A company spends two years overcoming immense difficulties to extract a technology from a public institution and then is designated as a transferee.
4. A company becomes aware of an artifact that has been created by a public institution. In order to produce a marketable product, the company must go back to the drawing board, using the technological form underlying the artifact as the basis for development. Although the company does 95 percent of the development work to produce a marketable product, the public institution is the developer and the company the implementor.

The two-element, one-direction model is misleading because:

1. It suggests that the transfer impetus comes from the institution in which the technology originates. This may be the case in some circumstances; but the relative degree of effort can only be judged after the fact. Under any circumstances, technology transfer does not occur without mutual effort and therefore should be understood as a cooperative endeavor.
2. The directional arrow does not encompass the transfer process. Technology transfer is not an event that occurs between two institutions, but a process in which they both participate.
3. The locus of value in technological development is radically misplaced in the originating institution. This causes the institution to overvalue what it has to offer, to withdraw into itself in the expectation that what it has to offer is sufficiently attractive, to disregard the needs of potential users, and to depreciate the efforts that must be expended by others to bring a technology to the point of innovation.
4. The technology to be transferred is presented as a discrete, fully developed item that is to be handed over in a process that has been reduced to an event. Transfer activities then center on communicating the results of what has been accomplished with the expectation that when transfer occurs, it will take place swiftly and smoothly.

IN SEARCH OF A DEFINITION

Paradoxically, transfer literature suffers from too much concentration on transfer events and processes. There are few articles on the nature of technology, though this is obviously a critical factor for an understanding of technology transfer. In addition, the context of transfer processes is not made clear. The innovation process is often mentioned, but generally as a private-sector affair to which transfer activities can make a contribution at given points in time.

A Possible Definition

In seeking a more adequate definition of technology transfer, it is best to leave aside, for the moment, questions about the nature of technology, since the subject is complex. This can be accomplished by simply including the word "technology" in the definition, without attempting to identify its meaning. An adequate definition at this point would be one that shifts the focus of concern away from transfer activities per se and toward the context of these activities by clarifying the relationship between technology transfer and innovation. Such a definition has been presented by Martin D. Robbins of the Colorado School of Mines in an essay on "Technology Transfer as a Process" (in A Synthesis of Technology Transfer Methodologies, U.S. Department of Energy, December 1984).

Robbins characterizes technology transfer as a special case of the technological innovation process. An innovation is defined in the conventional sense as the first application of an idea, practice, or object by the individual or institution that is applying it. The technological innovation process is described briefly as involving three essential steps: (1) the technology must have a source and must be created; (2) the technology must be produced or manufactured; and (3) the technology must be applied or used in some socially or economically profitable way.

Robbins then draws a distinction between technological innovation as an integrated and a nonintegrated process. In the integrated process, the steps in innovation are under single management control, which insures their integration. This is generally the situation within companies. In the nonintegrated process, the steps in innovation are not under single management control, either because portions of the innovation process are carried out by different organizations, or because the operating divisions within an organization behave as if they were separate organizations.

Robbins defines technology transfer simply as a nonintegrated technological innovation process. The definition avoids complexity and depends only on the concept that managerial integration of the innovation process is lacking. Technology transfer is not an event within the innovation process according to Robbins, but rather equivalent to the innovation process in circumstances of managerial discontinuity. Technology transfer is the innovation process when a technology falls under more than one management structure on its way to becoming an innovation.

Virtues

Robbins uses the definition for both descriptive and prescriptive purposes. The technology transfer that has taken place can be described as a nonintegrated innovation process. However, on the basis of lengthy experience with transfer efforts, Robbins concluded that much more could have been transferred if transfer had been understood as an innovation process rather than as a communications or applications process. The latter view attempts to make people aware of a technology after it has been developed, with transfer understood as a process of "getting it off the shelf." The former view enables technology to be approached in terms of development or adaptation so that it can be made transferable.

The definition appears to be adequate to describe the phenomena generally included under the title "technology transfer" and has the added quality of placing technology transfer within the context of a larger process that is better understood. Other virtues of the definition include the following:

1. Technology transfer is seen as a process rather than as an event. The dimensions of the process may be equivalent to the whole of the innovation process. Transfer begins at the point that a technology is designated for transfer (which may be at the beginning of the innovation process) and ends when the technology has become an innovation, or else is dropped from the innovation process.
2. The purpose of technology transfer is made clear. Transfer is not an activity that takes place for its own sake, but one that takes place for the sake of eventually achieving market acceptance of a technology or adoption by a public institution. End-use orientation is not something that needs to be added to the transfer process, but rather something that is integral to the process.

3. Transfer is conceived of as a cooperative innovation process. There are no initial assumptions about relative effort with respect to transfer or relative contribution with respect to development of the technology.
4. Technology transfer as a problem of the interface of institutions, which is often mentioned in the literature, is accentuated and broadened to encompass joint management of technology in terms of a common purpose. Technology transfer then becomes a primary concern for management, and jurisdictional overlap replaces handoff as the basic organizational relationship.
5. A new approach to transfer efforts becomes available, since the definition encompasses activities by which technologies can be groomed for transfer, rather than being restricted to instances in which something is ready for transfer. Technology management, as a way of looking at technology in terms of potential multiple applications and then developing the technology towards those multiple ends, then becomes a critical element in the transfer process.

Limitations

Although Robbins' definition appears adequate to the various technology transfer phenomena and provides points of emphasis that are extremely valuable, it has not been appropriated in the literature and will have difficulty in achieving widespread acceptance because:

1. Its meaning is not obvious and appears only through elaboration; and
2. It does not appear to address directly what most people are concerned with when they talk about technology transfer.

However, it is a useful working definition that should be clarified by an investigation into two critical terms in the definition: (1) innovation; and (2) technology. After these investigations, we may return to a reconsideration of the adequacy of Robbins' definition and a general discussion of the nature of technology transfer.

TECHNOLOGY

The word "technology" is derived from the Greek term technologia, meaning the systematic treatment of an art and including what we would mean by the fine arts as well as the mechanical arts. Techne was understood as a craft or skill geared toward production rather than toward action (as in politics) or toward purely theoretical knowledge (as in philosophy). The word logos refers to speech, account, or reason. The Greeks considered technology a type of knowledge because it was not an instinctive ability and could be acquired by learning. However, the mode of learning was not intellectual, since techne was transmitted by showing how something was done (through an apprentice system).

Since the time of the Greeks, the fine arts have been differentiated as a realm separate from technology, and technology has come to be associated with large-scale industrial production. Handicrafts, which are remnants of the original crafts that constituted technological activity, are now separated from technology and are considered to be oriented more on the production of beautiful, personalized objects than on useful objects that are mass produced.

During the 19th Century, the term shifted away from the productive arts in general (which include activities such as farming) and came to strongly suggest the mechanical and industrial arts as well as their knowledge content. Although this emphasis is still an important component of general usage, during the past few decades the term has begun to shift back toward inclusion of a larger realm of activity. An example of the broader definition of technology is presented by Robert Merrill (in the International Encyclopedia of the Social Sciences):

> Technology in its broad meaning connotes the practical arts. These arts range from hunting, fishing, gathering, agriculture, animal husbandry, and mining through manufacturing, construction, transportation, provision of food, power, heat, light, etc., to means of communication, medicine, and military technology. Technologies are bodies of skills, knowledge, and procedures for making and doing useful things. They are techniques, means of accomplishing recognized purposes.

Technology and Technologies

Merrill's definition concentrates on technology as realms of activity (e.g., farming) and extends to all of the practical arts as well as to what traditionally would have been called productive arts (e.g., manufacturing). Merrill's definition also makes a distinction between technology as a realm of activity (e.g., farming) and technologies (e.g., skills, knowledge, and procedures) as the means by which the practical arts are accomplished. Such a distinction is inherent in most discussions of technology, but the distinction is not made explicit.

If the distinction is made, we can speak of technology as the totality of the practical arts and as each of the practical arts separately and use the singular "a technology" and the plural "technologies" to refer to the means of which the practical arts are accomplished (e.g., a farming technique) as well as the things produced through manufacturing. The term "technologies" could be used in relation to the outcomes of practical arts other than manufacturing, but this would require that we speak of such things as foodstuffs (which are the productive outcomes of farming) as technologies.

"Technology" then encompasses the entire gamut of human activities concerned with the making and doing of useful things; and "a technology" and "technologies" refer to the means by which useful things are made and done as well as to the product-embodied useful things themselves. Since the means are themselves useful things, a technology is simply a useful thing (although, as we shall see, the "thing" that is useful is not equivalent to a physical object).

Given these distinctions, it becomes possible to employ Donald Schon's definition of technology (in Technology and Change) as an operational definition for many of the transfer activities of Federal laboratories. Schon defines technology as "any tool or technique, any product or process, any physical equipment or method of doing or making, by which human capability is extended." Obviously, Schon is using "technology" in the sense of "a technology" rather than in the sense of a realm of activity.

This is a good operational definition for technology transfer as a discipline because:

1. It concentrates on means rather than on activity. Obviously, technologies can be transferred, but technology in the sense of realm of activity (e.g., manufacturing) cannot except in unusual circumstances of underdevelopment. We must hold in abeyance, for a moment, the question of whether any of the components of technology as activity are transferrable.

2. It contains a distinction between means and products and therefore includes both of the commonly cited categories of technologies (product and process).

3. It extends the range of means to include various factors (e.g. methods) other than simply processes.

4. It offers a broad range of technologies that can be considered for transfer. In fact, it can be used to cover any of the hardware or means of doing or making employed in any of the practical arts.

5. It places emphasis on the function of technologies as extensions of human capabilities, thereby stressing the compatibility of technologies with human nature and their role in the expansion of human activity, rather than the traditional concept of technologies as survival mechanisms or implements for the conquest of nature.

Technologies as Things and Forms

Schon has provided a useful definition for technologies (as distinguished from technology as activity). Technologies are useful things that appear in a variety of modes, including the means of making as well as the things made. One major reservation must be placed on this definition, however, since it is misleading to identify technologies with products, tools, and physical equipment (which are some of the major components of Schon's definition). Although acceptable in general usage, this identification leads to confusion about the specific nature of technologies.

That something is made indicates that it is artificial; that it is a thing indicates that there is a physical manifestation; and that it is useful indicates that it is capable of being put to use. However, if we identify a technology with its physical embodiment, we miss the nature of technology, cannot understand the process of technological development, and make it impossible to speak of technology transfer as anything other than product transfer (which seldom occurs in cases other than those of international transfer).

Although the purpose of all manufacturing endeavor is the production of useful things, the things produced are not in themselves technologies; rather, they are embodiments of (or instances of) technologies. Your automobile, for example, is not a technology, but rather the physical embodiment of the form of the automobile (a selfmoving, wheeled vehicle designed for passenger transport), which is itself the technology and a composite of technologies.

The things that we use could not be if the technology did not preexist its physical manifestation. If we look back into the process of the creation and development of a product-embodied technology, we find that it begins as an idea in which a technical solution is envisioned for a need. The envisioned solution moves from the idea stage to technical confirmation (a paper proof of feasibility) to technical demonstration (often through creation of a prototype) and then through a long series of refinements, leading eventually to production. What is acquired (e.g., by the consumer) is an enfleshment of a technology that has been in existence for a long time before it assumes the particular physical form that is obtained by the purchaser or user.

Another reason why we should not identify a technology with its physical manifestation is that many technologies have a wide range of product applications. Such technologies are generally referred to as base technologies. Because of their wide range of applications, they often prove to be more valuable than single-application technologies. In addition, it should be remembered that most technologies never result in products (because they are abandoned for various reasons), which could hardly be the case if technologies were equivalent to products.

Obviously, many technologies would not exist apart from some physical manifestation. But, is the technology its physical manifestation, or is the technology something that is manifest in physicality? In everyday usage, specific products are often referred to as technologies. However, when people are challenged on this point, they invariably become perplexed and soon begin speaking of the object in terms of its use.

The essence of a technology apparently lies in its capacity to do something (its functionality), which is realized in use. A technology is what it can be used for (its potential for application) and is what it does (its actual application). Thus, the form that is manifest in physicality is simply an idea of utility. The idea would not be efficacious unless it was placed in some physical trappings, but the physical trappings can temporarily divert our attention from what the technology really is.

Since this language is somewhat confusing, an example is chosen for clarification. Is the paper clip on the desk before me a technology? If the previous analysis is correct, the answer to this question must be no. As an object, the paper clip is merely a piece of bent wire, which in itself is useless. This piece of bent wire can be spoken of as a technology (as happens in general usage) only because of the functionality that is operational through it. The essence of the paper clip is not its bent-wiredness, but rather the usefulness of this piece of wire as a temporary paper fastener.

The technological component of the paper clip is, therefore, its capacity to temporarily fasten papers together. A paper clip may be made of plastic or other materials and it may have a different form from the paper clip that lies before me. These are incidental to the temporary fastener technology.

The identification of a technology with its functionality should not be used to denigrate the physical embodiment. Unless the functionality were manifest in this particular piece of wire, I would not have the capacity to clip papers. In addition, an object as simple as a paper clip is a fascinating and complex thing. The wire must be bendable, it must be structured to hold and to slip easily on and off, it must be crimped at its ends so as not to tear the paper, and so on. These are elements of the lengthy process of design that must be addressed by anyone interested in making a successful product.

Technology as Activity

Keeping the distinction between technology and product in mind, Schon's definition can be used to cover technologies as means and products. However, his definition does not relate to technology as activity. It is important to address the activity of making for two reasons:

1. Technology is not reducible to technologies; that is, to the techniques and tools employed in making and to the outcomes of the making effort. As Peter Drucker has correctly observed in <u>Technology</u>, <u>Management</u> <u>and</u> <u>Society</u>, the subject

matter of technology is "how man does or makes." Technology is a specific mode of human activity that employs tools and techniques but must be understood in its own right.

2. An understanding of the work that is technology will give the laboratories a better understanding of their own efforts and the richness of the private-sector activities to which the laboratories can make a contribution through the transfer of technologies. In addition, an understanding of technology as activity has implications for technology transfer that transcend the transfer of technologies.

Obviously, it is impossible in this brief space to describe the technological work done in organizations. A few of the essential features of such activities will be identified through: (1) a distinction between science and technology, characterizing technology as a creative endeavor; and (2) a description of some of the major activities involved in manufacturing.

Technology as a Distinctive Activity

Technology as a realm of human activity is concerned with the making and doing of useful things. Making (e.g., in manufacturing) is something quite different from doing (e.g., in the extraction of minerals in mining). In addition, the things made vary in their artificiality. The production of foodstuffs through agriculture, for example, is more dependent on the realm of nature than is manufacturing.

Insofar as technology is primarily a making, rather than a doing, enterprise, it is an essentially creative activity. Manufacturing is generally understood as the exemplary case of technology. As a type of making, manufacturing brings new things into existence, including the radically new, modifications to something that was radically new, and duplicates of previously existing products. Creativity is manifest in product development (new and improved) and through the production process itself (i.e., through the manufacture of objects).

Creativity in manufacturing is directed toward the realization of something that is tangible: an artifact (or object). The artifact is artificial because it is manmade. The primary feature of the technological object is that it is useful: it is a thing intended for use.

Use is the primary determinant of design, more important even than cost. What is valued by the purchaser (or obtainer) is not the artifact itself but what the artifact can be used for (i.e., its utility).

With this basic understanding, which concentrates on the manufacturing model, we can contrast technology with the fine arts and with science. The fine arts are akin to technology in that they are creative and involved in making. However, making in the fine arts is largely an end in itself, and the thing made is not meant to be useful but beautiful. When the art object is presented to the public, it is not meant to be used but contemplated. The art object is valued for the effect that it has on the contemplator. The technology is valued for what can be made or done with it.

"Science" is used in the sense of activity and of the product of that activity. Neither the activity nor the product of that activity are concerned with making, but with knowing. Science seeks to know that which is (primarily the natural, but also the artificial), and its product is knowledge. Science does not seek to create but to discover. What is discovered may be useful, but its utility is not a function of science.

Technology is not applied science. This model, which still prevails in popular literature, is no longer accepted by the scholars of either science or technology. It can be dismissed on the simple grounds that the Chinese produced an extraordinary technology before the 15th Century without any science, that almost all innovations in the West until the beginning of the 20th Century had little to do with science, and that although the importance of science to technological innovation is increasing, it is still not a predominant factor in most technological activities.

Although technology is not applied science, the two are not unrelated. The relationship, however, is complex and reciprocal. The influence of science on technology is generally accepted, but the reverse relationship is not widely understood. With respect to the technology dependence of science, two examples should suffice. The first is that of the telescope and microscope, implements that were developed without benefit of scientific theory, but implements that have been fundamental to many scientific breakthroughs. The second is that of the transistor, generally used to illustrate the dependence of technology on science. Although the invention of the transistor was dependent to a degree on previous scientific advances, it was the invention itself that led to the explosion of solid-state physics in the universities.

In the 20th Century, technology has become more science dependent, just as science has become more technology dependent (witness the impact of computers on scientific research). There is a greater degree of cross-fertilization, which is becoming increasingly essential to the health of both. But, the degree of cross-fertilization should not be exaggerated. The picture of science and technology that emerges from recent scholarship is that of two semi-autonomous, weakly interacting realms with their own distinct structures and dynamics.

The impact of science on technology is sometimes dramatic, as, for example, in the rapid formation of biotechnology out of the scientific discovery of the structure of genetic material. Generally, however, the influence of science on technology is subtle and long term, with science making numerous contributions to technological development.

The Technological Enterprise

For the following discussion of various aspects of making, manufacturing is chosen as a basis because it is the quintessential technological activity with products as the intended outcome. In considering manufacturing as an activity, it is necessary to address: (1) technological knowledge; (2) the action of production; (3) the organization of production; and (4) the mode of production. The focus of production is on the things produced, since knowledge, action, organization, and mode are geared toward the making of useful things. However, the things produced are not part of the activity, but rather the result of the activity, and thus have been discussed previously as a separate item.

Technological Knowledge

In the section on "Technologies as Things and Forms," it was pointed out that a technology cannot be identified with its physical emodiment. A technology is not really what a thing is, but what it does. It generally begins as a concept of potential use that gradually increases in embodiment until it achieves the final specificity of a product. By understanding a technology as an envisioned form that increases in concreteness over time, we are automatically pushed back to the knowledge components that drive the activity of making.

The processes that enflesh technological forms and produce a series of products are primarily in the hands of men who deal with things rather than with ideas. This is not to say that modern technologists are merely craftsman, working by trial and error, without benefit of scientific theory. It does mean that the modern technologist shares more in common with the traditional craftsman than he does with the academic scientist, and that when science is used, it generally serves as a background knowledge.

This background knowledge is becoming increasingly important to the modern technologist. It consists of those portions of science that have proven to be important to technology, as well as the systematized portions of technological practice. Together, these constitute the disembodied knowledge base of technology.

Nevertheless, technological knowledge can only be carried in part through formal theory. It is a body of practical knowledge constituted by tradition and rules of thumb gained from experience. The guiding principles can be demonstrated in practice, but they cannot be fully expressed, because they are composed of technical expertise, previous practice, and bits and pieces of scientific law. All of these are manifest in personal skills that are designated as knowhow.

The modern technologist and the traditional craftsman exercise intelligence, but the understanding that is applied is more of a tacit understanding (in the heart and hand) than an understanding in the mind that can be elaborated in terms of general principles. It is an empirical, rather than a theoretical, knowledge that must be learned primarily by experience (by "getting one's hands dirty"), including a great deal of failure.

Technological Action

This knowledge is applied in a synthetic manner that puts the material world together rather than breaking it up analytically for theoretical purposes. The process is systematic and rational, but must proceed by trial and error. It is directed toward the resolution of material problems and therefore is heavily dependent on sight. It is object specific, seeking the particular solution rather than the general application.

The technologist loves things and is interested in making them. Thus, his activities are more like those of the artist than the scientist. The things that he makes must be useful; that is, directed toward the satisfaction of human needs, including the needs related to the appearance of products as well as the needs related to utility. As a consequence, the technologist must be market oriented if his activities are to be successful.

Design, which is concerned with structure and appearance, is the essence of technological action. Design is knowhow manifest in action and directed toward the production of something useful. Design begins with the envisionment of a material solution to an identified need and proceeds through a detailed plan or design, prototype development, and full manifestation in things made. The technologist must weave together, and operate under the constraints of, the materials at hand, the processes of production (whether old or to be built for a new product), and, most especially, the requirements of the market.

The action of making begins with a preconceived end and is regulated by that end. What is to emerge from the making process must be of a certain size, of particular materials, of reasonable cost, and so on (depending on whatever the market specifications might be). Thus, design is the enfleshment of a technological form in keeping with the requirements of use.

Technological Organization

The organization of making has changed dramatically through the rise of the modern firm as a large-scale, integrated system focusing on innovation in a competitive environment. Technology, as activity, has become an organized and systematic discipline.

Innovation occurs through the introduction of new products, modifications to existing products, and improvements in the production process, all occurring under the spur of competition and therefore requiring such things as speed, flexibility, inspiration, market orientation, quality control, and cost consciousness. The organization must be looked at as a system, requiring the coordination of many different specializations, activities, and processes, as well as the coordination of men and machines toward a common end. Management and its techniques have thus become areas of primary concern.

Another significant change has been the emergence of the research laboratory as an important initiator of innovations. The research laboratory brings together a large number of specialists whose knowledge and skill is applied to a common problem and directed toward specific technological outcomes. Invention is increasingly becoming a collaborative effort.

A third factor is what one might call a loosening of the institutions. Generally, we think of the firm as an autonomous organization with a single end, content to rely on its own resources. The modern firm, however, is quite often diversified, relies on others to accomplish major portions of the productive effort (sometimes on an international scale), is nested within a system of dependencies in which the products and services of other firms are essential to its own productive effort, and is looking for innovative ideas from outside. The correlative of loosening is greater interaction, collaboration, dependency, and fusion.

Production Modes

The modes of production obviously include such things as processes and techniques, which we have referred to as technologies. However, in considering technology as an activity, the focus of attention shifts away from the tools of production and towards the problem of how men interact with their tools.

Productivity increases are not merely a matter of acquiring better machines. They also rest on gaining more from the worker. Manual labor was transformed into a highly productive activity when the tools were taken for granted and attention was directed toward the work effort itself, with the intent of enabling the worker to use his tools more effectively. The first investigations in "scientific management," for example, where concerned with how to make shovelling more efficient.

The systematic study of work has given rise to disciplines such as industrial psychology (dealing with problems such as fatigue) that are essential to quality control. There has been a greater incorporation of intelligence in work. The knowledge worker has supplanted the manual worker, giving rise to new problems in the stimulation of productivity increases. Machines have been invested with intelligence, requiring even greater intellectual capacities on the part of workers.

TECHNOLOGICAL INNOVATION PROCESS

An innovation is something newly put to use, whether an idea, practice, or artifact. Innovation is also the act of using something new. The application may be by an individual or an institution. The newly used may be something quite old, but when adopted for the first time by an individual or institution, it is an innovation for that individual or institution. Given this definition, it is obvious that innovation can be nontechnological as well as technological.

The innovation process is the process by which the something newly used moves from conceptualization through adoption. However the process is represented, its intentionality is directed toward adoption and is completed through adoption. The something newly used is something put to use. When efforts directed toward innovation do not result in use, we can say that the innovation process has failed.

It is important for Federal laboratories to understand the innovation process for two reasons:

1. By their very nature, most Federal laboratories are concerned with technological innovation, since they have been created for the development of useful things. Even though the laboratories do not produce products, most primary mission

activity is directed toward things that are to be used. Thus, laboratories are participants in the innovation process, playing a role in the early stages of development. In order to be successful (from the perspective of the public, which looks for results), they must orient their efforts on what is to emerge from the overall process, with due regard to the context of application.

2. With respect to the secondary mission of Federal laboratories (i.e., technology transfer), the laboratories need to be aware of the specifics of the innovation process as it occurs in the private realm. The problems with which the private sector must deal, the points within the innovation process at which companies may be seeking external assistance, and the way in which companies employ technical information obtained from external sources are factors that Federal laboratories must take into consideration if their transfer activities are to be successful.

Models

The innovation process is generally represented by a series of hierarchically ordered boxes, usually beginning with research and moving to development, then production, then marketing. This is not a model of the innovation process per se but of the technological (or technical) innovation process. Other innovations (e.g., a social innovation) would require a different model, since most of them are not manifest in anything tangible.

In addition, the standard model is directed toward product development. It attempts to illustrate how new products are introduced. This would restrict the realm of technologies to those that can be embodied in products (including the hardware of processes). However, if we consider technology as well as technologies and use an expanded definition of technologies, such as that presented by Donald Schon, the standard model is only partially applicable and cannot be used to describe the innovation process for such things as techniques, the organization of production, and process understood as form (rather than as hardware).

Given this limited context, the standard model attempts to illustrate how technological or scientific knowledge is translated into a physical artifact that is marketed as a new product. This model has been useful as a first approximation to the product innovation process.

However, attempts to explain real-world processes in terms of the model have revealed a number of serious limitations:

1. The illustrated process is much too orderly and does not reflect the messiness of real-world situations. This is the case with most models and can be overcome only to some degree through complexification.

2. The model in its various representations generally does not end with adoption and therefore does not really complete the innovation process.

3. Generally, there is one direction of movement with no feedback mechanisms (though this can be included by arrows). The importance of market concerns to research effort is not, for example, usually illustrated.

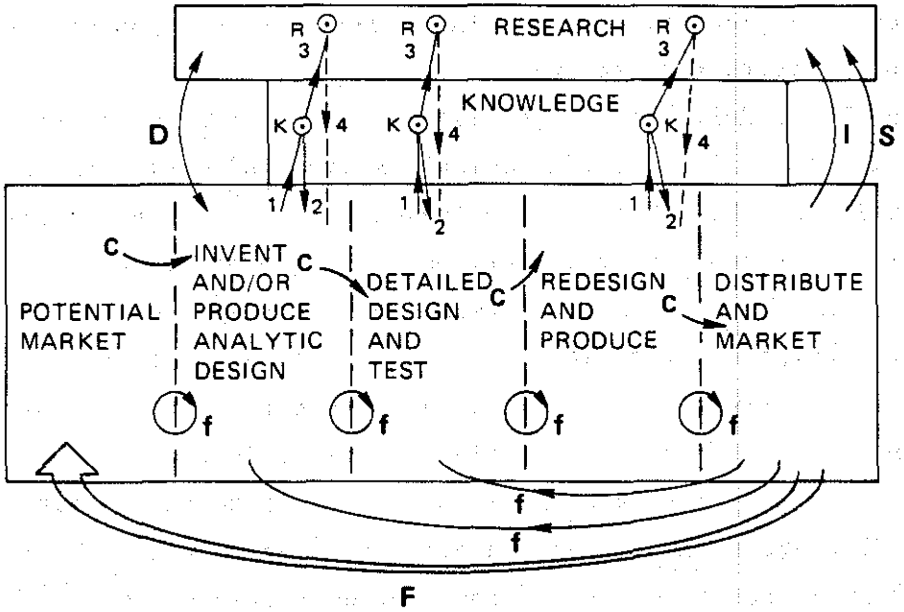
4. The boundaries between stages of the process are well defined and do not illustrate overlap and reversals.

5. The stages of the process can also be read as organizational components (with research, for example, conducted by a research department). Obviously, this occurs only within the larger firms that have the capacity for structural differentiation. However, even in these cases, the innovation process is now often carried out by project teams with members representing the various organizational components.

6. Any model devoted to new product development misses out on the bulk of innovation, which occurs through incremental improvements to previously existing products and processes.

7. The question of what constitutes a new product is held in abeyance. Any diagram of the innovation process that begins with research strongly suggests dramatic breakthroughs. This has been tempered to some degree by distinctions between major and minor innovations. But, if one looks at the actual nature of innovations, they appear on a continuum ranging from the dramatic to the infinitesimal.

An attempt to correct these deficiencies by proposing a new model has been made by Stephen Kline and Nathan Rosenberg (in Ralph Landau and Nathan Rosenberg, eds., The Positive Sum Strategy). The proposed model, which is illustrated in Figure 1, is called the chain-linked model because it emphasizes continuous linkages between the central chain of innovation and existing and new knowledge. The critical virtues of the model are that it: (1) illustrates the normal



SYMBOLS:

C = Central-chain-of-innovation.

f = Feedback loops.

F = Particularly important feedback.

K-R = Links through knowledge to research and return paths. If problem solved at node K, link 3 to R not activated.

Return from research (link 4) is problematic--therefore dashed line.

D = Direct link to and from research from problems in invention and design.

I = Support of scientific research by instruments, machines, tools, and procedures of technology.

S = Support of research in sciences underlying product area to gain information directly and by monitoring outside work. The information obtained may apply anywhere along the chain.

Figure 1. Chain-Linked Model

innovation procedures in the existing firm engaged in product improvement and expansion of the product line; (2) places a heavy emphasis on market orientation; (3) identifies design as the most important feature in the innovation process; and (4) places research as a contributor to the process rather than as an initiator.

Within this model, "knowledge" refers to existing knowledge, whether of a scientific or technological nature, and "research" refers to the activity of obtaining new knowledge, as well as its outcome. Under normal circumstances, when persons in a firm become aware of a market opportunity, they first determine whether they have the knowledge to invent what is needed. If not, they go first to other colleagues in the firm, then to literature, then to external experts. Research is undertaken only if existing knowledge is insufficient to resolve the problem. Reference to existing knowledge and research is continuous throughout the innovation process on an as-needed basis.

The chain-linked model is an important advance over the traditional model, but it suffers from three inadequacies:

1. The process does not end in use; thus, the innovation process is incomplete.
2. Potential market is not a stage in the innovation process, though it is important to point out that it is generally an initiating factor.
3. Although design is emphasized, the richness of the design process is not displayed.

An older model developed by Sumner Myers and Donald Marquis (in <u>Successful Industrial Innovations</u>) resolves some of these problems. One rendition of the Myers-Marquis model is presented in Figure 2. It has the following advantages:

1. The origin of the design concept as a synthesis of demand and technical feasibility recognition is displayed graphically.
2. The innovation process ends with use.
3. The process is presented as a flow in time, rather than simply as a timed sequence. It is therefore a good model for displaying product improvement as an innovative process that is continuous.

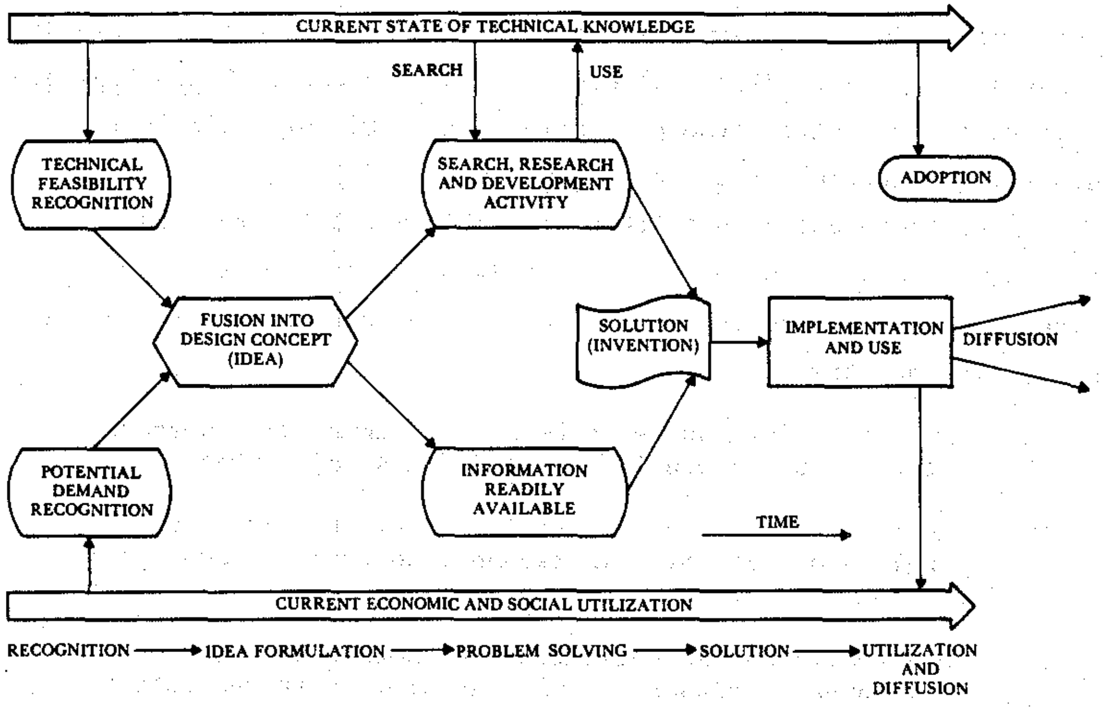


Figure 2. The Process of Technical Innovation

This model suffers from a heavy concentration on the invention phase and does not include a development phase. These deficiencies are partly remedied by another rendition (presented by Marquis in "The Anatomy of Successful Innovations," Innovation, November 1969), which is presented in Figure 3. This rendition includes the development stage, but it does not show the richness of design. Such richness is displayed in a model (Figure 4) used by Donald Schon in Technology and Change that was derived from D.W. Karger and R.G. Murdick's "Managing Engineering Research" (Machine Design, April 1963).

It should be noted that Schon uses this model for critical purposes, since he does not accept a view of invention or innovation as rational, ordered processes. With respect to invention, for example, Schon points out that:

1. Invention often works backward from intriguing phenomena rather than forward from well-defined objectives.
2. Invention is full of unanticipated twists and turns. It is a juggling of variables in response to problems and opportunities discovered along the way.
3. Need and technique determine one another in the course of development; neither is fully determined at the outset.
4. It is not always apparent ahead of time from what disciplines or technologies answers will come.

Schon is undoubtedly correct in such assertions, which are verified by numerous examples in his book. If innovation is not a rational, ordered process, it cannot be presented in a model; or, rather, many models would be needed to cover the various forms of innovation. A particular model can be used to initiate thought and order the process to some degree, but the complexity of innovation can be understood only through practice or through immersion in case studies.

In spite of these caveats, the modified Myers-Marquis model (Figure 3) can be used as a second approximation of the innovation process. It should be pointed out that this model was developed specifically for the more "mundane" forms of innovation, such as product improvement, rather than for the introduction of radically new

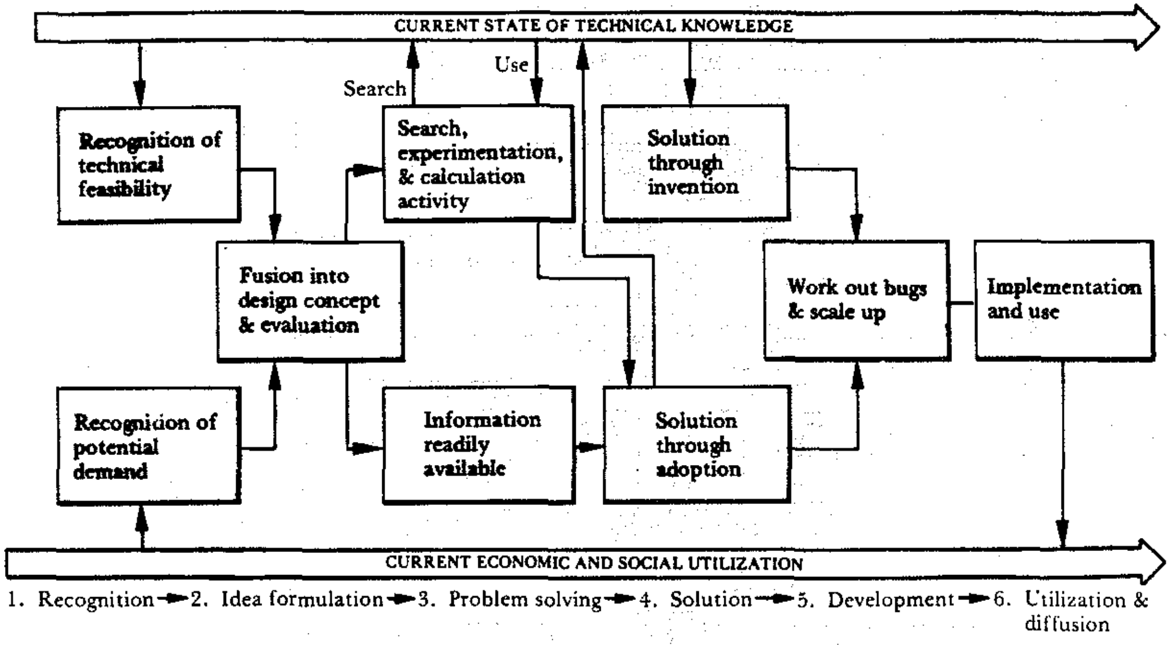


Figure 3. The Process of Innovation

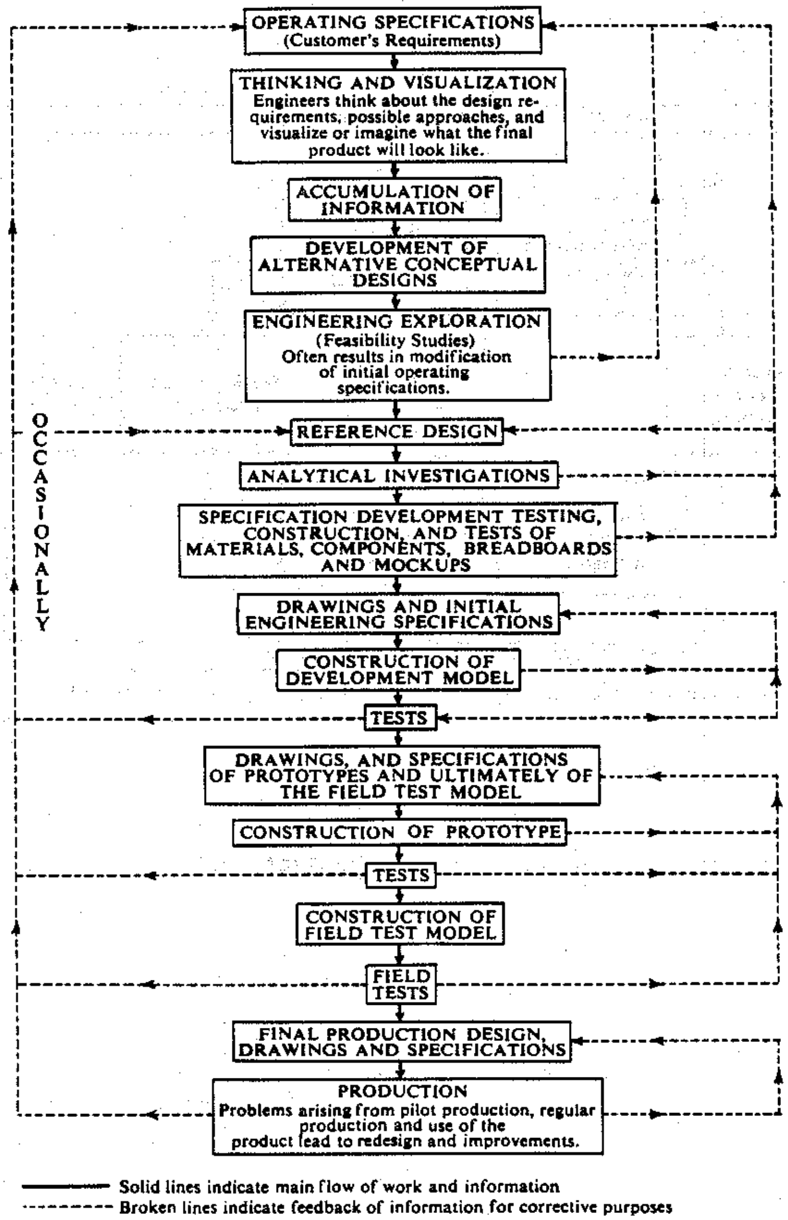


Figure 4. Product Design Process

products. The latter element could be incorporated by a synthesis of the Myers-Marquis and chain-linked models that would include a research component above the "Current State of Technical Knowledge" flow line in the Myers-Marquis model.

The Myers-Marquis model does not contain the complex feedback mechanisms of the chain-linked model, but it does illustrate the primary feedback mechanism, which occurs as a result of utilization. Most importantly, the flow arrows are continuous. Implementation of a product modification gives rise to a new current state of economic and social utilization that then becomes the basis of subsequent product modifications.

The two primary dangers in using the Myers-Marquis model are as follows:

1. The graphic display automatically suggests that the innovation process is concerned with the introduction of radically new products. This is, of course, the opposite of what Myers and Marquis were attempting to accomplish. The use of such terms as "design concept" cannot suggest how small some of these designs actually are, or that the modified product is usually a collocation of a multitude of small changes.

2. The model suggests that implementation occurs through product introduction. However, a great deal of innovation occurs through modifications to the production process that are developed internally within the firm or else acquired from outside. Such improvements, both large and small, are important contributors to increased productivity, and the small are likely to occur on a continuous basis (as part of everyday operations). In this sense, the firm is its own market. The Myers-Marquis model can be read in this sense, with "solution through invention" representing production improvements invented within the firm and "solution through adoption" representing production improvements acquired from outside the firm.

Distinctions

Although the innovation process cannot be completely formalized, certain aspects of the process can be clarified. Initially, four key terms--technology, invention, product, and innovation--need to be distinguished. In considering these terms, it should be kept in mind that the discussion operates entirely within the manufacturing realm, though none of these terms can be restricted to manufacturing.

We have spoken of technology as activity and of technologies as the means by which such activity is accomplished and as the outcome of such activity. In considering the latter factor, we have found that a technology cannot be identified with the product in which it is embodied. When, then, can it be said that a technology has come into existence, and what is the relationship between a technology and an invention and a product?

Following the Myers-Marquis diagram of the innovation process (Figure 3), we find that a technology begins to be formed when a technical solution is envisioned for an anticipated demand (which is often expressed as need or opportunity). These factors are fused into a design concept. The design concept is, of course, an idea and not a thing. The idea contains within itself two features: (1) a sense of use (which is the quality underlying demand); and (2) a sense of how that utility can be realized through a material solution.

The design concept is risky, because the envisioned technical solution may be wrong; indeed, there may be no technical solution. There is a search of existing knowledge and research for new knowledge if needed, and then, perhaps, an invention, which demonstrates the validity of the design concept.

Like innovation, the word invention is used to refer to an action and the results of that action. An invention is something newly created. If we speak of a technology at the design concept stage, we are forced to conclude that a technology precedes its invention. Thus, it is better to say that a technology comes into existence at the point of its demonstration and that before that point we are dealing with a technological concept. Given this distinction, a technological invention is simply a newly created technology.

In the invention, the sense of use and its potential realization expressed in the design concept are actualized. Use is embodied in matter. As Donald Schon has pointed out, invention is itself generally a process rather than a discrete event. The actualization takes time, is dependent on numerous subsidiary inventions (each of which has its own development trail, no matter how small), and is usually the work of many hands.

It is often objected that many inventions, particularly in the realm of new materials, do not begin with a design concept. It is said that a new material can be accidentally discovered, so that we are faced with a solution looking for an application. However, this way of speaking is misleading. One does not recognize a new material as a new material without a concept of use. The word "material" contains within it a sense of use. If what is seen is understood merely as an accident, then the accidental is discarded. What happens accidentally becomes a technology when it is seen in terms of potential utility.

In the case of the "accidentally discovered" new material, the design concept and its solution are realized at the same time. The important point is not whether a technology follows a sequence of development such as that presented in the Myers-Marquis model; rather, it is that every product-oriented technological invention is a synthesis of use and its material satisfaction.

Products are things produced by companies for sale. They are technologies packaged in keeping with the needs of specific groups of potential users. A product is a technology (or usually a complex of technologies) dressed for market. Many technologies have a multitude of different product manifestations. Thus, when we speak of use and its material embodiment in the invention, the use in question is not necessarily a product-specific use, and the invention is not the product.

Most inventions never result in products. When they do, the product often bears little resemblance to the invention, and the invention may be incorporated in many products. The use embodied in the invention is obviously an intended, rather than an actual, use, since the invention cannot be used until it is put in product form. Often, the use embodied in the invention is a general use; in these cases, the uses embodied in a range of products are subsets of the general use.

The distinction between product and invention is important because people purchase products and not inventions or technologies, though they are interested in the utility contained within the products. An invention is generally a long way from a product, and most development costs lie ahead as the design process refines and dresses the invention in terms of market specifications. In addition, since it is the product and not the invention that is actually purchased, the conceptualization of the product is generally of far greater importance than the invention itself and is sometimes called the second invention.

Products are not innovations unless they are purchased and put to use. An innovation is, therefore, a product adopted by the market. Innovation as action by entities external to the producing firm is the completion of the innovation process. However, using the Myers-Marquis model, we can see that the completion of the process is the beginning of a new process; for, when the product enters the market, feedback occurs and the product is modified for a new introduction.

DIMENSIONS OF TRANSFER

We began with Robbins' definition of technology transfer as a managerially nonintegrated technological innovation process. This definition is important because it stresses that transfer is not an end in itself but that it intends innovation. The definition also clearly expresses the fact that transfer involves relationships between organizations or components of an organization. However, it does not generally express what most people mean by technology transfer.

The subsequent discussions of technology and the technological innovation process have left Robbins' definition largely intact. Robbins is sensitive to the fact that the innovation process cannot be restricted to new product development, and he points out that in the case of such things as techniques, the middle term in the creation-production-application schematic for the innovation process may be skipped.

The discussion of the innovation process has revealed one serious problem with Robbins' definition. The innovation process ends with use. If the user is an organization, Robbins' definition holds good. However, if the user is a consumer, the innovation process cannot be completed by an organization. Unless we wish to call the consumer a manager, technology transfer cannot be a managerially nonintegrated innovation process for the most common innovations (i.e., consumer products). In addition, many cases of international technology transfer involve applications by individuals (e.g., farmers) rather than by organizations.

Although Robbins' definition is not perfect, it could, if adopted, provide an important tool for the Federal laboratories to gain a better understanding of what they are doing and to do their jobs better.

Most Federal laboratories have been created for the sake of innovation; that is, their efforts are devoted to the development of things that are to be used by others; and to the degree that they have done their jobs properly, the effort results in an adoption (i.e., an innovation). However, the laboratories neither produce nor sell. They do not managerially control the whole innovation process, but must pass on the results of their efforts to others who then continue the innovation process. Thus, the laboratories are participants in a managerially nonintegrated innovation process, and most of their activities can be considered technology transfer.

This is the view that many laboratories have of their own activities. When laboratories report on their technology transfer activities, they divide these activities into two types: (1) direct transfer where research is conducted and brought to application for a specific client group, whether in the public or the private realm; and (2) "spinoff" or secondary use of technology where the user is not part of the clientele for whom the research originally was conducted. The first type of transfer activity is equivalent to the work conducted by the laboratory in keeping with its primary mission. The second type of transfer is connected with the laboratory's secondary mission, recently established for all Federal laboratories through legislation.

Reformulation

Obviously, a perfectly adequate definition of technology transfer (one that would cover all of the identified forms of technology transfer and express the essential quality that they share) has eluded us. Strategically, however, we are not so much interested in a general definition of technology transfer as in one that would be applicable to the Federal laboratories and not provide as wide a divergence from general usage as Robbins' definition does.

In _What Every Engineer Should Know About Technology Transfer and Innovation_, Louis Mogavero and Robert Shane point out that to an engineer, "technology" does not refer to a physical thing. As a consequence, when we speak about the transfer of technology, we really mean the transfer of knowledge. In addition, transfer does not mean movement or delivery, but rather the use of knowledge. Nothing has been transferred unless it has been applied. Thus, Mogavero and Shane define technology transfer as the use of knowledge.

If we draw together the insights of Mogavero and Shane along with our discussions of technology and technological innovation, we can propose for use by the Federal laboratories the following definition:

> Technology transfer is the process by which information concerning the making and doing of useful things contained within one organizational setting is brought into use within another organizational setting.

This definition does not cover cases of international transfer where products, rather than information, are brought into application. However, it does cover cases of transfer between organizational components of a company, because the primary mode of transfer is informational, even when the production component of an organization is faced with transfer problems in relation to the marketing component.

This definition has the following advantages for use by the Federal laboratories:

1. It indicates that technologies and technology are generally transferred as information. Such information may be verbal or written. However, transfer can also occur through observation of knowhow in action (through personal contact), or through observation of techniques and methods manifest in operations. In observation, acquisition replaces transmission as the mode of transfer.

2. It indicates that transfer is a process rather than a discrete event. The dimensions of the process are not identified, except to say that it is terminated through application. Application may occur solely within the firm (e.g., as a technique), or there may be an initial application within the firm for product development purposes that eventually results in a product application.

3. It identifies the specific content of the information (i.e., concerned with the making and doing of useful things). But, it does not restrict the information to what would generally be called technologies. Rather, it includes all information conducive to the technological enterprise.

4. It identifies transfer with use. Nothing has been transferred unless it has actually been used. This shifts the focus of transfer activities toward the concerns of users, rather than producers, and relates transfer to the innovation process.

5. It does not make any assumptions about the status of the technology or technologies that are transferred. Transfer may be simple application, or it may require development or adaptation, either within the user organization or jointly between the user organization and the containing organization.

6. It does not convey any suggestions about who is doing the transferring. Generally, joint efforts are required. However, transfer can occur in some cases almost entirely through the efforts of users. In any case, the fact that transfer terminates in use means that the user must always play a prominent role.

7. It indicates that technology transfer is a problem of interchange between organizations.

8. It does not make any assumptions about where the information originates. The information might have been developed by the containing organization; it might have been acquired from another organization; or it might have been developed through joint research within the containing organization conducted by the containing and obtaining organizations.

9. It does not suggest that anything is lost by the containing organization. Information can be widely disseminated without any loss to the disseminator.

Transfer of Technology and Technologies

We have spoken of technology as a realm of activity (the practical arts collectively), as specific realms of activity (such as farming), and of the various components of activity (such as design in the manufacturing realm); and, we have spoken of technologies as the means of making and doing as well as the things made. Probing deeper into the things made, we have found that a technology cannot be identified with its physical manifestation. Although things made are necessarily physical, their technological essence lies in their utility (i.e., a technology is essentially what it does). The task before us is to relate these distinctions to the transfer activities of Federal laboratories.

With respect to technologies, Schon's definition of a technology as "any tool or technique, any product or process, any physical equipment or method of doing or making, by which human capability is extended" has been appropriated as an operational definition because it provides a wide range of opportunities for the Federal laboratories to contribute to technological development, including the means of doing and making as well as the things made.

The limitations of this definition for the purposes at hand are threefold:

1. As has been pointed out, it is incorrect to identify a technology with a product. A technology (or usually technologies) is manifest in a product but is not the same as its physical form.

2. Some of the technologies enumerated by Schon are usually transferrable only under circumstances of international technology transfer (where it is meaningful, for example, to speak of moving objects from one country to another). In the case of technology transfer from Federal laboratories, it is not the technology itself that is transferred, but rather information about the technology (i.e., information about products, processes, tools, techniques, and so on), which may be couched in terms of rights to the technology.

3. The information transferred is often not about a complete technology, but rather about components of a technology. In this sense, a Federal laboratory can make a technological contribution rather than formulating a complete technology.

With respect to technology as activity, it is obvious that it is not meaningful to speak of the transfer of the technological realm (i.e., the practical arts). Nevertheless, particular realms, such as manufacturing, may be practically nonexistent in a severely underdeveloped country, so that we could speak of the transfer of manufacturing activity to that country. Obviously, this would not be of concern to the Federal laboratories.

A second aspect of the transfer of technology as activity relates to the components of the technological realms. Some of the components of manufacturing were used as examples, with discussions of knowhow, design, and organization and the relation of man to tool. In what sense is it meaningful to speak of the transfer of these activity components?

One approach would be to collapse technology as activity into our definition of technologies, since the activities themselves, as well as the specific instances enumerated, could be covered by a concept of "method of doing or making by which human capability is extended." The activity of design, for example, could be spoken of as a method.

This would require an expansion of Schon's definition beyond its apparent emphasis on discrete items, which we have classified as technologies. The important point is how we understand the dimensions of the terms used. Much of what we have called activity can be reduced to method or technique as long as we understand the terms to include such things as management and organizational techniques or the resolution of stress problems in space that could be applied to commercial airlines and underwater diving. Federal laboratory management and personnel should understand that anything that makes a contribution to the extention of human capabilities falls in the realm of technology transfer.

Nevertheless, there is a sense of activity that is not reducible to technique. The ability to invent and design and the capacity to make (both of which fall under the broad category of knowhow) are properties of persons. Skill embodies techniques but is not reducible to them.

One of the major aspects of technology transfer is not from the Federal laboratories to other institutions, but rather within the laboratories themselves. It is called on-the-job training and occurs when incoming employees gain or increase their capacity for technological work by working with senior employees in whom skills are embodied.

Another major aspect is from the laboratories to other organizations and lies in the movement of people. Skill contained within the laboratories and to one degree or another acquired within the laboratories is transmitted to other public organizations and to the private sector through job change. Such persons may also carry with them specific techniques and even ideas for products. However, their greatest value is in their expertise. Although such processes have not been fully documented, they probably represent the major current of technology transfer from Federal laboratories.

Capacity, skill, expertise, creativity are embodied qualities that cannot be transferred in the form of information and require the movement of people. Thus, such forms of transfer lie outside of our definition. This is not a particularly important problem, since laboratories cannot be expected to institute personnel turnover mechanisms as a technology transfer policy, although such things as personnel exchanges definitely fall within the scope of legislatively intendended transfer activities.

Science Into Technology

We have made a sharp distinction between science and technology and addressed some of their relationships. The relationships are important to Federal laboratories because much of their work is considered scientific in nature. Most laboratories do not engage in production (which is done on a contract basis) and seldom even develop prototypes. For the person who considers his activities to be scientific in nature, it is difficult to see the relationship with the technological realm.

However, the scientific dimensions of laboratory work should not be exaggerated. Much laboratory work is in applied research, which has making and doing as its intended outcome and therefore is a form of technological activity. Basic research in the laboratory is indeed pure science because it seeks knowledge for its own sake. However, such research is generally funded by the public for its potential contributions to applications. Thus, most basic research conducted in Federal laboratories should be understood as technology-related science.

Whether directed toward application or directed toward knowledge for its own sake, laboratory research produces new information about the nature of the world, and this is what is generally called science. It would seem that the transfer of scientific information would not be a species of technology transfer. However, if we define technology transfer as the use of information in the technological realm, science transfer can be seen as a type of technology transfer; for, when science is appropriated in the technological realm, it is transformed into technological information. The appropriator is not interested in expanding his knowledge of the world for its own sake, but rather in appropriating scientific information for use in technological endeavors.

The laboratories produce a great deal of new knowledge, some of which is related to making and doing and some of which is limited to the uncovering of new aspects of reality. The knowledge related to making and doing would appear to be more amenable to transfer to the private realm. However, much of it is largely restricted to mission objectives; and, even in the case of purely scientific research there are potentials for application, as, for example, when laboratory personnel publish scientific papers that filter into technological realms at the interface between science and technology.

Knowledge transfer through publication is an extremely important component of technology transfer. Unfortunately, it is extremely difficult to document the influence of such knowledge on technological development, since the influence is generally subtle and long term. The user is quite often the only one who can recognize the potential applicability of such knowledge, and the knowledge generally merges with other types of information in such a way that its distinctive contribution cannot be identified.

Personal Dimensions of Transfer

In speaking of technology transfer as the use of information, we should not assume that transfer takes place merely, or even predominantly, through formal publications. These may serve to catch the eye and stimulate interest, but this is only the beginning of a generally lengthly process. The mode of transfer from organizations such as Federal laboratories is always in the form of information; but such information may be acquired verbally, through observation, and through joint development work, as well as through written media, and written media are not equivalent to formal publications.

One of the major conceptual advances in the field of technology transfer occurred during the 1966 MIT Conference on the Human Factor in the Transfer of Technology (published as Factors in the Transfer of Technology, William Gruber and Donald Marquis, editors), which came to the conclusion that "the mechanism of technological transfer is one of agents, not agencies; of the movement of people among establishments rather than the routing of information through communications."

Unfortunately, this insight has become a cliche, with the assertion that technology transfer is a people process. Like most cliches, this one is true in the sense that technologies do not move themselves. The efforts of persons are required; but there is more to the matter than that.

The various essays in Factors in the Transfer of Technology dealt with the movement of people, carrying with them personal skill, techniques closely related to skill, and information about specific technologies. The conceptual advance emerged out of these essays rather than being the principle on which the conference was conducted. Rather than becoming a cliche, the insight should have led to two questions: (1) What is the nature of technology such that it is transferred most effectively by the movement of people?; and (2) What is the nature of technological knowledge such that it cannot be effectively transmitted through the mere routing of information?

In the case of activity transfer, the case is quite clear, since skill can move from one organization to another only through the movement of people. But what of technologies? It has been found that the transfer of technologies generally requires some form of participation on the part of the person or persons who were instrumental in developing the technology or are acquainted with its use.

The international transfer of technology quite often involves the transmission of products (e.g., a foot pump for irrigation in Africa). Such cases invariably involve adaptation of the technology to conditions of use in the new setting and to the requirements of users who are culturally quite different from the users for whom the product was originally designed. Even the simplest of technologies are often unusable in the new context unless someone who knows how to use them accompanies the technology in order to provide a demonstration and perform the necessary adaptations.

Adaptation and training-in-use are widely recognized as necessary components of international technology transfer when dealing with underdeveloped populations. However, similar problems exist at all levels. Norman Hummon, for example, reporting on a survey of how multinational corporations transfer technologies to enterprises in other countries, makes the following point:

> It is very rare for technology transfers to be made without a technical assistance agreement. The purpose of this agreement is to transfer the know-how necessary to use the technology to the recipient company. In short, the agreement attempts to ensure transfer of the art of the transferred technology as well as the technology itself. Indeed, respondents to the survey ranked the quality and extent of the company's know-how of greater importance in the pricing of technology than patents, trademarks, and other company characteristics. ("Organizational Aspects of Technological Change," in Rachel Laudan, ed., The Nature of Technological Knowledge)

Although the example is drawn from international technology transfer, problems connected with use of the unfamiliar are socially pervasive. Apparently, the essentials of use cannot be fully conveyed through an instruction manual, even with the simplest of use objects, as most of us have experienced from time to time in attempting to follow written instructions for household and yard equipment. In the case of more sophisticated equipment (e.g., photoduplication machines), the more successful companies conduct training programs for users and are on call to answer specific questions of application.

The best place to obtain information on use is from one skilled in use; that is, from one who has knowhow. This knowledge is most effectively transmitted by demonstration, then by adjustment of new-user behavior through tutelage. This particular aspect of the personal dimensions of transfer may not be of great interest to the laboratories, since they seldom transfer products. However, even a simple technique may require demonstration and adaptation to specific requirements of use in the new setting.

Most transfers from Federal laboratories do not involve things that eventually become salable products. Insofar as the technology to be transferred is product destined, it will either be at some early stage of development or else embodied in a product that was developed in terms of mission objectives. For the latter case, the mission product will have a particular form and composition that keep it from being immediately applicable to commercial purposes. Generally, extensive changes and refinements are necessary to place the underlying technology in a new form of concreteness for purposes somewhat different from those that controlled its original design. Conversely, if the technology is in an early stage of development, extensive work lies ahead before a product can be realized.

In either case, development to salable product is a lengthy and expensive process. Since products are produced by companies, a firm may choose to do the development work in-house, or it may join with a Federal laboratory to engage in joint development work. If the work is done in-house, the inventor (or inventors) within the Federal laboratory may be requested to join in the development work through consulting, a technical assistance agreement, or even a leave of absence. At times, a company may be able to do all the work in-house without benefit of outside assistance, particularly in circumstances in which its own personnel have been working with closely related technological problems. But generally, some form of assistance from the originator is needed.

The problem within the context of Federal laboratory operations has been expressed by Jon Soderstrom in an essay on "New Initiatives in Technology Transfer: Introducing the Profit Motive" (in the Utah Innovation Foundation's First International Technical Innovation Entrepreneurship Symposium). Soderstrom, who is with the technology transfer office at Oak Ridge National Laboratory, points out that technology transfer is not a handoff, but rather an exchange demanding significant interactions between the parties, and that government-funded inventions are usually primitively demonstrated ideas that need considerable refinement before they are ready for the commercial marketplace. As a consequence:

> For the technology to successfully complete the innovation process and enter the marketplace, both the originator and those responsible for the subsequent development and commercial exploitation must contribute. Without the inventors the product developers cannot hope to completely understand the new technology. Conversely, without the product developers, the inventor cannot hope to see it produced on the market.

This is not a problem restricted to public agencies, but exists within the private realm when a technology is transferred from one operational division of a firm to another. The need for inventor participation in the development effort is described by Michael Martin in Managing Technological Innovation and Entrepreneurship (on the basis of comments by Lowell Steele in Innovation in Big Business):

> What will already be obvious to most experienced scientists, engineers, and technology managers in industry is that technical know-how cannot be transferred purely "on paper." It is virtually impossible to document exhaustive, detailed, unambiguous, and error-free specifications for a project. Much of the experience and insight built up by solving the problems and overcoming the "bugs" endemic to successful project progression can never be meaningfully documented on paper. Part of this learning experience may be incorporated in revised specifications and instructions, but inevitably duplication of learning must occur, which may be minimized if at least some members of the R&D project team are personally involved in the transfer process. The "operations" project team then has immediate access to the R&D team's experience and knowledge whenever bugs arise. In fact, it may be argued that it is virtually impossible to transfer technology effectively without "people transfer" (at least temporarily), through intraorganizational secondments.

From these examples it becomes obvious that it is difficult to describe a technology on paper. This is not a problem with science, which deals with ideas, since ideas by their very nature are fully representable on paper. When we enter the world of concreteness, however, potentials for description are endless, since words cannot fully capture the dimensions of an object.

The secret of a thing made is hidden in the knowhow of its making. This in why reverse engineering is a specialization requiring knowhow. The question of reverse engineering is not so much What is this? as How did they do this? The answer to the latter question can be provided only by one who knows how; that is, by a person thoroughly familiar with the making of a particular type of technology who can retrace the thought processes and developmental steps that went into the making of the thing that lies before him. This is also why it is exceedingly difficult to reconstruct an existing object when the knowhow of its making is lost (as has been the case, for example, in attempts to build a replica of the Newcomen engine and reconstruct the methods used by medieval masons for vault construction).

Such problems are particularly acute when a technology is in an early stage of development, when the relationship between the knowhow of the maker and the thing-in-making is particularly intimate. The potentials of the incipient technology, if it can be modified, how it can be modified, how it will react in different product manifestations, how it will function when being used for different purposes, problems that can be expected along the way, and so on are questions best addressed to the maker or makers.

Technology transfer is a people process that goes beyond the formal transfer of information in publications. But the process is not one that merely requires interaction between a firm and a transfer agent. The technology developers must be part of the process, often working in conjunction with the firm because of the very nature of technology and the knowhow of its making.

TRANSFER PRINCIPLES

We have proposed for use by the Federal laboratories the following definition of technology transfer:

> Technology transfer is the process by which information concerning the making and doing of useful things contained within one organizational setting is brought into use within another organizational setting.

However, we have also found that this definition does not cover one of the most important transfer processes from Federal laboratories:

the transfer of embodied skill through the movement of people. A more adequate definition can be proposed through the inclusion of an additional term:

> Technology transfer is the process by which information and abilities concerning the making and doing of useful things contained within one organizational setting are brought into use within another organizational setting.

In order to accentuate the fact that the information referred to in the definition is not restricted to formal publications, the word "knowledge" can be substituted for "information." In addition, the abilities referred to in the definition are what would be called embodied knowledge. Thus, a final rendition of the definition would be as follows:

> Technology transfer is the process by which knowledge concerning the making and doing of useful things contained within one organizational setting is brought into use within another organizational setting.

This definition should cover all aspects of technology transfer from Federal laboratories, including the transfer of technology as well as technologies. It can be used to cover the normal transfer activities between existing organizations, but is also applicable to conditions in which a person from a Federal laboratory leaves to start up a new company, carrying with him acquired technologies as well as embodied technical ability.

Such a definition may be misleading if it is taken out of the clarifying context that has been elaborated in this issue paper. In addition, although the definition may be adequate to cover most transfer from the public sector to the private sector, it is deficient for other applications in which product-embodied technologies are transferred. The most glaring deficiency is in the largest realm of technology transfer; that is, in international transfer, which often involves products and frequently involves individuals, rather than organizations, as recipients of technologies.

Nevertheless, the modified definition appears to be adequate for the transfer activities in which Federal laboratories are involved. A critical feature of this definition is the identification of parameters for technology, for without a concept of technology, a Federal laboratory cannot be in a position to identify that which it should be transferring.

We have defined technology as the realm of human activity engaged in the making and doing of useful things, encompassing the practical arts and including the various ways in which men make and do within each of the practical arts. And, we have defined technologies (or a technology) as the means by which useful things are made and done as well as the product-embodied useful things themselves.

Donald Schon's definition of technology as "any tool or technique, any product or process, any physical equipment or method of doing or making, by which human capability is extended" has been proposed as an operational definition for the transfer of technologies (or a technology) from Federal laboratories. This definition offers to the Federal laboratories a broad range of technologies that can be considered for transfer. And, it has been pointed out that "method of doing or making" can be used to cover various aspects of technology as activity.

One serious limitation of this definition is that it identifies some technologies as products. Our analysis of the nature of technologies led to the conclusion that a technology can have a physical form (i.e., as a product), but that a technology should not be identified with its physical manifestation. The essence of a technology is its capacity to do something, which is realized in use.

This insight is important because Federal laboratories do not have any market-ready products to transfer. They do, however, have many technologies. Some of these are embodied in things that have been produced as a result of mission work, but they must be extracted from the thing if they are to be useful for applications other than those for which the thing was designed.

Many Federal laboratory technologies are not product-embodied. And, given the nature of Federal laboratory work, many have not reached the stage of prototype development. Their physicality is incipient rather than complete. Thus, in attempting to identify technologies for transfer, Federal laboratories should concentrate on the functional essence of technologies rather than on physical features that may be misleading.

Most importantly, it should be recognized that Federal laboratories deal with a wide range of transferrable technologies. Those that are susceptible to product embodiment may not be the most important, nor the easiest to transfer. A management technique developed in a Federal laboratory may be more important to technological progress than a series of laboratory-originated products, and it may require little modification for application in a new organizational setting.

Two of the most important contributions of Federal laboratories to technological progress lie in the training of personnel and the generation of scientific information. The movement of people with embodied skills is the primary mode of technology transfer, but this is an area in which laboratories are reluctant to claim credit. In addition, scientific information filters into the technological realm, but the process is difficult to document.

For most cases of transfer, and particularly for those that are product related, the laboratories should look upon their efforts as contributions to technological progress. If a technology originating in a laboratory eventually results in a product, development costs borne by the private sector will usually be far in excess of the cost for the creation of the technology itself. In most cases the laboratory-originated technology may be one of many technologies embodied in a product. And, the creative insight that recognizes the product potential of a laboratory-originated technology may come from the external source rather than from the laboratory.

In cases other than the movement of people, information is the vehicle of transfer from Federal laboratories. However, information is not equivalent to formal publications. Written information may include such things as design plans, sketches, and engineering data. Other information may be acquired verbally and may involve protracted discussions. In addition, information may be acquired merely by observation of others in action and the technologies upon which they are working. Joint development work provides a mixture of verbal, written, and observational exchange.

Throughout this paper, the underlying theme of all of the definitions presented has been use. A technology is a useful thing; an invention is a synthesis of a concept of use with its material satisfaction; the innovation process terminates in adoption; and technology transfer does not take place unless the transferred information is actually used. Use is the unifying principle in all aspects of the technological realm.

Most Federal laboratories have been created for the development of useful things, and their activities are part of various innovation processes, whether through primary mission work or the secondary mission of technology transfer. This is the case even with respect to most "pure" scientific research conducted in the laboratories, which generally has been funded for the sake of its potential contributions to technology.

Deficiencies in the products of some mission work, which are well known and much discussed, are generally rooted in a lack of clarity throughout the development process with respect to the requirements of use. The other side of this coin is a fascination with the emerging technology itself, which leads to overdesign, high expense, and the creation of objects that are not suited to the needs of potential users. Even within their primary mission work, Federal laboratories have much to learn from the market orientation of the private sector and the design process in the private sector.

With respect to the secondary mission of technology transfer, the Federal laboratories are confronted with the problem of identifying other applications for technologies developed as part of the mission work. As a first step, it is necessary to identify the inventions themselves, which are often overlooked because they were created not for their own sake, but to accomplish other goals. Second, the technological essence (its base functionality) must be separated out from the specific use for which the technology was developed. Third, other applications must be identified.

The last element is particularly difficult for persons who are not used to thinking about a wide range of potential commercial applications. Such limitations can be overcome to some degree through creativity training and internal evaluation boards, but generally the insights of persons external to the laboratory such as firms and brokers are needed.

For those technologies that have commercial potential, additional development work is almost always needed. Such work may be carried on independently by the Federal laboratory to prepare a technology for transfer, but this should never be done without an expression of interest from external sources and at least some marketing work. Development work may be carried forward by the external organization, but this usually requires some participation of laboratory personnel because of the hiddenness of technology in the knowhow of its maker.

Joint development work is the ideal because it involves the sharing of costs and risks and secures the participation of the technology's creators in the development process. For development work on processes, there are opportunities for research consortia. However, if a technology is being groomed for a product manifestation, the relationship with the laboratory will almost always be that of a single firm. Such development efforts give the laboratories greater insight into private-sector concerns and enable the design process to be firmly oriented on market specifications.

The dual mission imposed on the laboratories by technology transfer combined with primary mission work places the laboratories in a situation quite similar to private-sector organizations with large, R&D components. Many decades ago, such organizations began to look upon their R&D efforts as investments from which maximum value should be obtained. This required looking at technologies not only in terms of their product potentials, but also in terms of what could be done with them if they were not pursued through product development.

Many large firms have established components that license and barter unutilized or underutilized technologies (and also bring technologies within the organization). Such components are technology transfer mechanisms similar to those that are being formed in Federal laboratories. In fact, it was these private-sector activities that inspired the initiation of transfer activities in the Federal laboratories.

Technology management is dealing with technologies in terms of multiple purposes. Just as the private-sector looks at its technological capital in terms of applications in addition to product development, the Federal laboratories have been mandated to look at their technological capital in terms of the dual applications of primary mission work and transfer in order to realize maximum value from public investments in R&D.

The Federal laboratories are in a unique position to engage in technology transfer. They have a much stronger technological orientation than most universities, and their mandate to pursue the public good through technology transfer enables them to exercise greater flexibility than the private sector in the use of funds for development work.

<u>Issue Paper III</u>

INNOVATION AND THE PRIVATE SECTOR

Issue Paper III

INNOVATION AND THE PRIVATE SECTOR
Gellman Research Associates, Inc.

DEFINITIONS

Before considering invention, technology transfer, and innovation, it is necessary to advance a few definitions. (Figure 1) First it is essential to distinguish between invention and innovation. (Figure 2) "Invention" is the discovery of a phenomenon; it is a device or a process which is the result of study and experimentation. "Innovation" was defined by economist Joseph Schumpeter as "something newly tried." It is the culmination of a process through market introduction, on an arm's length basis, of a product or service which is new *in the context of that market*. Innovation may be technological or otherwise. (A pricing innovation would be a good example of the latter.)

The terms "technological possibility" and "technology delivery" are also useful. A technological possibility is the result of a "successfully" concluded research and development (R&D) phase of the process of innovation. Technological possibilities are the key raw materials from which technological innovations are fashioned. Technology delivery refers to the elements in the process of innovation which follow the conclusion of the R&D phase of the process. Consequently, technology delivery encompasses all tasks and issues necessarily addressed if a technological possibility is to reach the market, thereby concluding the process of innovation.

To recap, invention is to *conceive* as innovation is to *use*. But innovation is also a *dynamic* term. It is a *process*--a *complex process* by which an invention or idea is translated into a product or process and brought into a marketplace.

Further with respect to "technological possibilities," when they remain on-the-shelf in a laboratory or firm, they can properly be considered to be "contingent assets"; successful technology transfer and successful management of innovation processes converts these contingent assets into *earning or producing* assets.

Finally with regard to definitions, the phrase "technology transfer" refers to the movement of technologies and techniques over

Figure 1

A FEW DEFINITIONS

INVENTION — "DISCOVERY OR FINDING; PRODUCTIVE IMAGINATION; DEVICE, CONTRIVANCE OR PROCESS ORIGINATED AFTER STUDY AND EXPERIMENT."

INNOVATION — "SOMETHING NEWLY TRIED". CULMINATION OF A PROCESS THROUGH MARKET INTRODUCTION, ON AN ARM'S LENGTH BASIS, OF A "NEW" PRODUCT OR SERVICE. MAY BE TECHNOLOGICAL OR OTHERWISE. FUNDAMENTALLY A "PEOPLE" PROCESS.

TECHNOLOGICAL POSSIBILITY — THE RESULT OF A "SUCCESSFULLY" CONCLUDED RESEARCH AND DEVELOPMENT PHASE OF THE PROCESS OF INNOVATION. A KEY "RAW MATERIAL" FOR A TECHNOLOGICAL INNOVATION.

TECHNOLOGY DELIVERY — THE ELEMENTS IN THE PROCESS OF TECHNOLOGICAL INNOVATION WHICH FOLLOW THE "SUCCESSFUL" CONCLUSION OF THE R&D PHASE. TECHNOLOGY DELIVERY ENCOMPASSES ALL TASKS AND ISSUES NECESSARILY ADDRESSED IF A "TECHNOLOGICAL POSSIBILITY" IS TO REACH THE MARKET AND THEREBY CONCLUDE THE PROCESS OF INNOVATION.

Figure 2

WHAT ARE INVENTION & INNOVATION?

INVENTION . . . TO CONCEIVE . . . THE IDEA

INNOVATION . . . TO USE . . . THE PROCESS BY WHICH AN INVENTION OR IDEA IS TRANSLATED INTO A PRODUCT OR PROCESS AND BROUGHT INTO THE MARKETPLACE.

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space and between entities (public and private) including industries and firms. And, always technology transfer takes place over time. (Figure 3)

MOTIVES FOR SUPPORTING TECHNOLOGY TRANSFER AND INNOVATION

Why should any firm or government agency in a fundamentally private enterprise economy devote resources to technology transfer and innovation, either to generate technological possibilities or to exploit them, regardless of their source? As for private entities, they either seek to stimulate demand for their own output, to reduce the cost of producing that output, or to achieve both results at the same time. (Figure 4) An example of the latter can be found in the commercial jet transport aircraft industry where unit costs of production were reduced from prior levels while at the same time there was an increase in demand for their services because they were more comfortable, faster, more reliable, and, at least initially, were quite glamorous. Most often, however, innovation produces only one of the two results and not both.

Industry also supports technology transfer and innovation when it becomes necessary to deal with an actual or expected competitive threat, to meet an imposed growth objective, or to cope with a regulatory requirement--such as an environmental clean-up edict. An expanded, more finely cut list of motives driving industry to engage in technology transfer and innovation includes anticipated profits from the investment in innovation, the hope of besting the competition, and the fact that the enterprise has a history and heritage of successful--that is to say profitable--innovation. (Figure 5) Also, some firms seek primarily to enhance revenues through technological innovation, although this is not usually a wise course because revenue maximization is <u>not</u> a legitimate goal of the entrepreneur; but <u>profit</u> maximization is. It should also be recognized that image, as derived from the generation and use of technological possibilities, is important for some firms as is the achievement of corporate diversification objectives.

All of these motives and the resources available to serve them are conditioned by the structure of the market in which a firm operates.

Figure 3

TECHNOLOGY TRANSFER

- BETWEEN NATIONS
- BETWEEN INDUSTRIES
- BETWEEN ENTERPRIZES
- VERTICAL TRANSFER
- HORIZONTAL TRANSFER
- TRANSFER AND TIME
- PUBLIC SECTOR → PRIVATE SECTOR
- PRIVATE SECTOR → PUBLIC SECTOR

Figure 4

BASE MOTIVES FOR SUPPORTING INNOVATION
(PRIVATE SECTOR ENTERPRIZE)

- DEMAND STIMULATION
- COST REDUCTION
- BOTH OF THE ABOVE

- TO DEAL WITH A COMPETITIVE THREAT (ACTUAL OR EXPECTED)
- TO MEET A GROWTH OBJECTIVE
- TO MEET A REGULATORY REQUIREMENT

Figure 5

OTHER MOTIVES FOR SUPPORTING INNOVATION

- PROFITABILITY
- COMPETITIVE RESULTS
- NATURE OF THE ENTERPRISE
- GROWTH OBJECTIVES
- INCREASE OF REVENUES
- IMAGE
- SOCIAL BENEFITS > SOCIAL COSTS*
- POLITICAL ADVANTAGE*
- TRADE STIMULATION
- DIVERSIFICATION

*PUBLIC ENTERPRISE

(Figure 6) For example, if someone is functioning in the admittedly theoretical purely competitive markets (best approximated perhaps, by production of agricultural commodities in a totally unregulated economy), he is not able to accumulate the resources necessary to invest in technological innovation. He barely makes a living and in some years may not do even that.

At the other extreme, the literal monopolist usually has no incentives to invest in technology transfer and innovation because it has all the market. (Figure 7) Such a firm certainly has the resources to support innovation but no need to compete--and it is the need to compete which is the most powerful motive of all. In the middle, most often characterized as oligopoly by economists, both the need and ability to innovate are usually present and, fortunately for U.S. society, most enterprises are in the middle as far as market structure is concerned.

To sum up on this point, the enterprises that have the greatest need for promising technology--the ones near the most competitive end of the spectrum that want to move to a higher level of prosperity--cannot afford to innovate, while those firms that can afford it most need it least. Put still another way, monopoly power and the <u>propensity</u> to innovate are inversely correlated while monopoly power and the <u>ability</u> to innovate are directly correlated.

What of government agencies, including publicly-supported laboratories? Of course there are unique responsibilities of government (e.g., health and safety defense) which can only be discharged with the support of substantial R&D activities and outcomes. Beyond this, government has an obvious stake and responsibility in assuring that the national economy grows and prospers, and the shared public and private use of publicly funded research outcomes and technological possibilities serves such purposes as jobs are generated and U.S. international competitiveness is enhanced generally.

Figure 6

MARKET STRUCTURE AND INNOVATION

- “PURE” COMPETITION
- OLIGOPOLY AND “EFFECTIVE COMPETITION”
- “SHARED MONOPOLY”
- REGULATED INDUSTRY
- NATURAL MONOPOLY
- MONOPOLY

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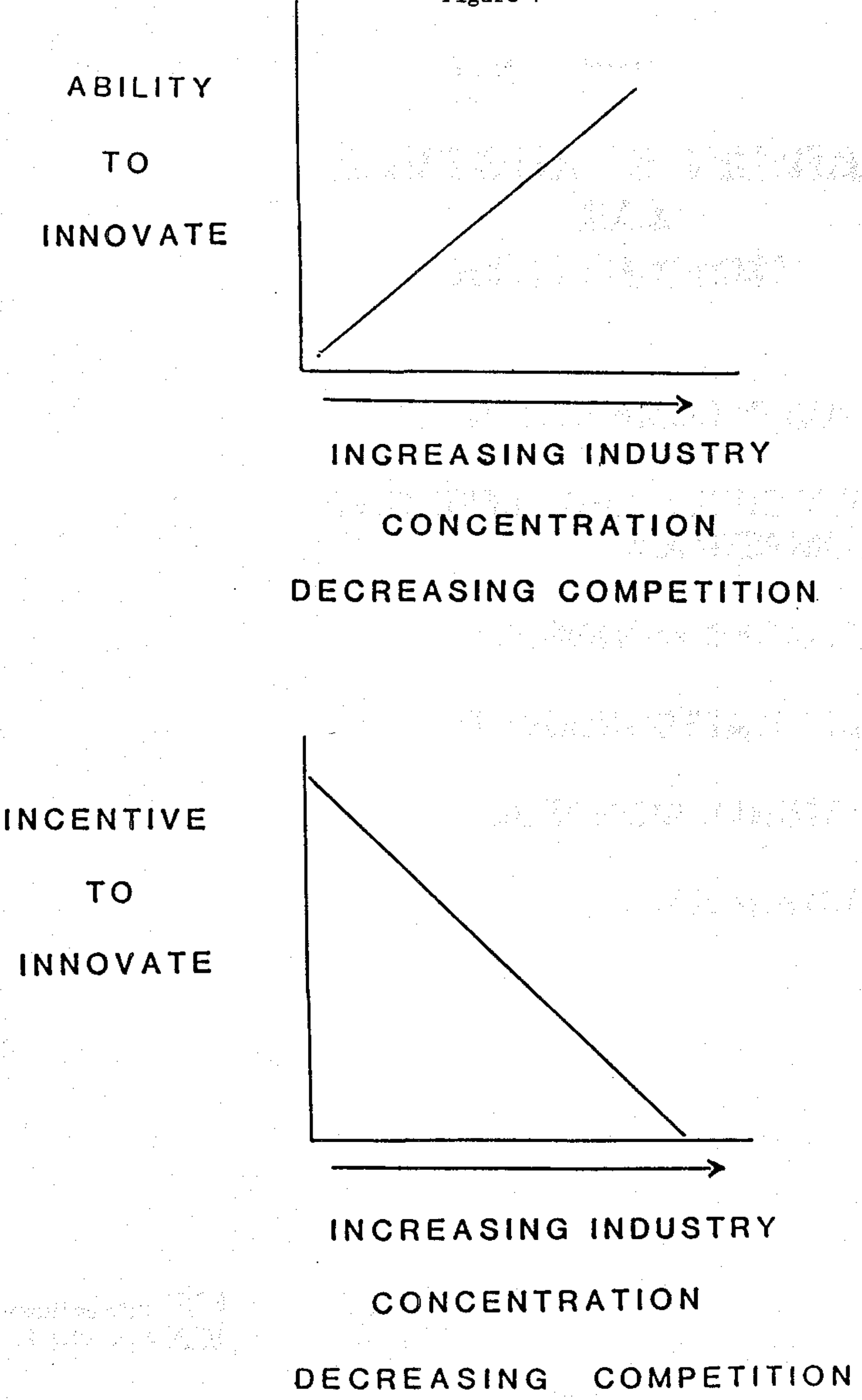
Figure 7


ABILITY TO INNOVATE
INCREASING INDUSTRY CONCENTRATION
DECREASING COMPETITION
INCENTIVE TO INNOVATE
INCREASING INDUSTRY CONCENTRATION
DECREASING COMPETITION

INNOVATION AS A PROCESS

Earlier, innovation was referred to as a process in which technology transfer is a possible technique for realizing the objectives of innovation. It is now necessary to specify the process of innovation with somewhat more precision. (Figure 8) The process begins with invention or conception, progresses through the R&D phase, traverses the production and marketing elements of the technology delivery portion of the process, and finally results in introduction to the market of a new product (or service) on an arm's length transaction basis. No one says this process always has to be profitable. There only has to be market introduction to complete the process of innovation itself.

The process of innovation can be depicted in more detail--and must be treated in such a manner in order to manage skillfully specific innovation processes. Short of a fully-descriptive model is the one depicted in Figure 9 (which actually goes beyond the innovation process since that process is completed, by definition, with the item referred to as "first delivery").

Also generally relevant to the process of innovation is the fact that carrying out the process of innovation in its entirety is not achieved with the speed of light. It takes a considerable period of time in most cases. In fact, from a study done some while ago, but which still provides the only data on the point which are available, it can be said that industrial innovation, from invention to market introduction, typically takes years--many years--usually in the range of five to 10. Moreover, this is the case in all industrialized nations. (Figure 10)

Another useful way to view technological innovation is by determining the ultimate locus of the technology which is central to it. This is not as complicated as it sounds. Technology, and therefore technological innovation, is either product-embodied, is manifest in production processes, or is reflected in management techniques and results. (Figure 11) Excellent examples of each can be drawn from civil aviation:

- The active-controls concept as first embodied in a civil transport by Lockheed in the L-1011-500 long range aircraft;

Figure 8

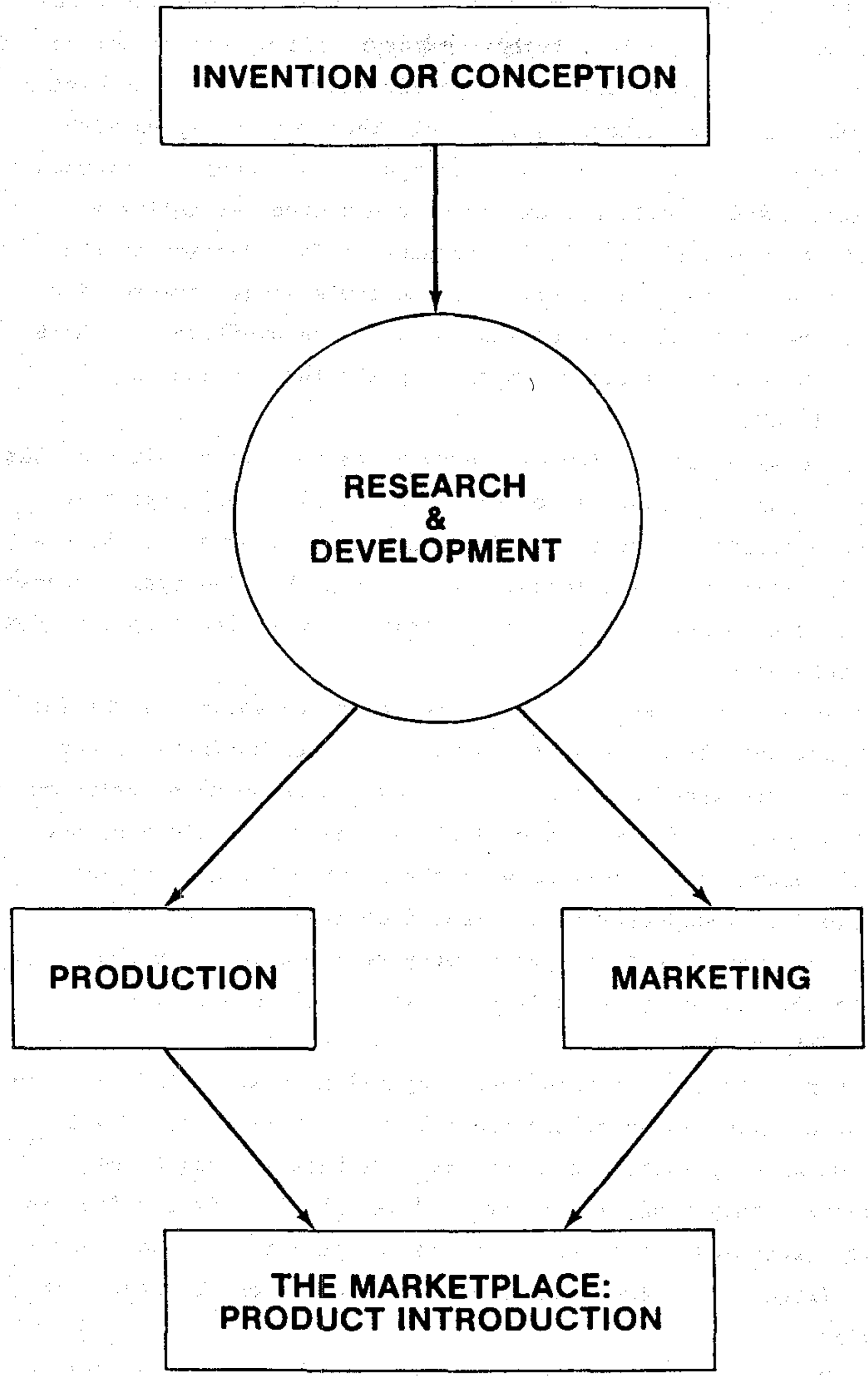
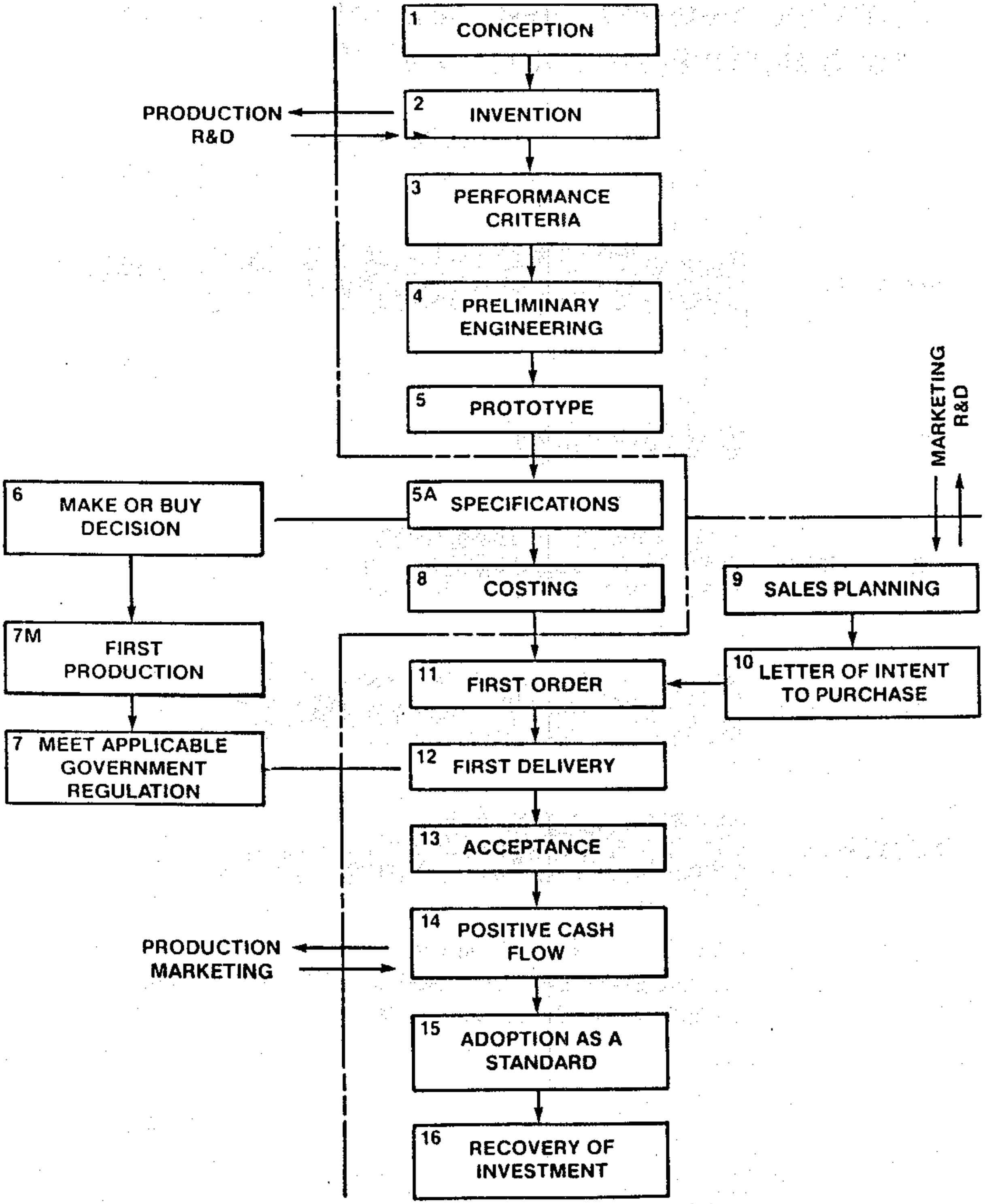

INVENTION OR CONCEPTION
RESEARCH & DEVELOPMENT
PRODUCTION
MARKETING
THE MARKETPLACE: PRODUCT INTRODUCTION

Figure 9

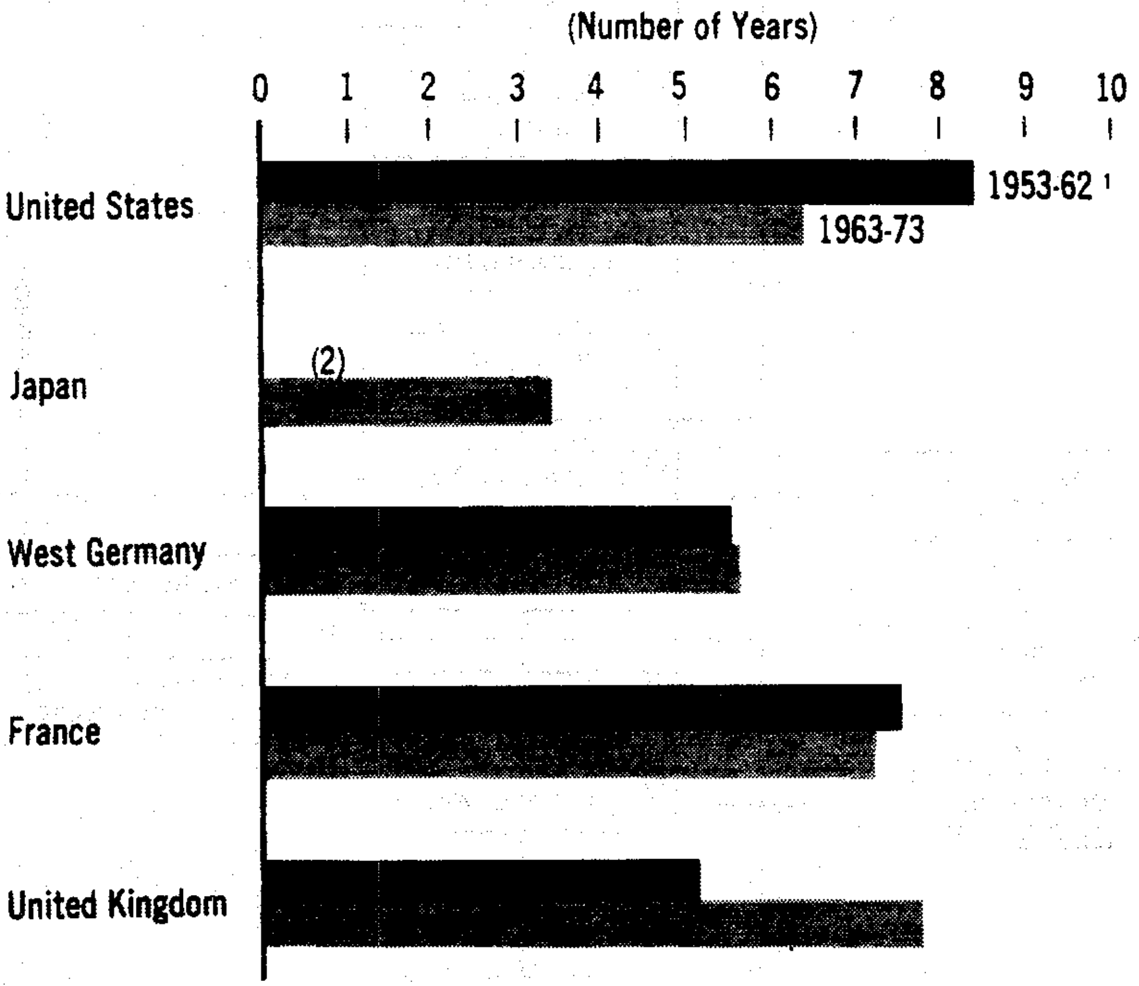
KEY ELEMENT MODEL OF THE PROCESS OF INNOVATION



Source: Gellman Research Associates

Figure 10

Interval Between Invention and Innovation, for Selected Countries, 1953-73



[1] Refers to the date of the innovation.

[2] Sample size does not allow calculation of the time interval.

SOURCE: Gellman Research Associates, Inc.

Figure 11

TECHNOLOGY: ONE CLASSIFICATION SCHEME

PRODUCT — EMBODIED TECHNOLOGY

PROCESS TECHNOLOGY

MANAGEMENT TECHNOLOGY
AND TECHNIQUE

- The dry-joining technique used exclusively by Boeing in some of its airframe assembly operations;
- The paperwork management process reflected also at Boeing in its Everett, Washington plant where the 747 and 767 are assembled.

It is now appropriate to emphasize that neither "technology transfer" nor innovation involve just technology. In fact, innovation, whether technology transfer is a part of the process or not, is much more fundamentally a <u>people</u> process. People can make or break a technology transfer; people can promote or thwart an innovation. Substantive research and experience indicates that the people nature of the process of technological change and innovation is never more dramatic than when one or a few people with sufficient leverage oppose a change, a technology transfer, or the continuation of an innovation process. Put another way, a most effective way to promote innovation and achieve technology transfer is to find a <u>champion</u> for the technology.

It is also helpful to recognize that the initial force behind an innovation process emanates from a supply-push or a demand-pull situation. The availability of research outcomes and technology at government laboratories is an example of a supply-push innovation situation. A firm or industry recognizing the need to solve an environmental problem (like acid rain) sets up a demand-pull innovation process. (Figure 12)

Supply-push can be characterized by the phrase "I have. Don't you need?" While the demand-pull parallel is "I need. Don't you have?" Upon examination of these statements, there is no difficulty in identifying the stronger of the two. Demand-pull innovation is clearly easier to bring off that supply-push. This partially accounts for why there has been so little innovation driven by technology transfer from government and university laboratories. It also suggests that those who seek to transfer technology from such sources of R&D results will be more effective if they explicitly seek to create or promote demand-pull pressure. There are several ways of achieving this result. Among the most powerful is the development and use of "market relevance statements" as part and parcel of any basically supply-driven program of technology transfer. (Figure 13)

Figure 12

THE GENESIS OF INNOVATION

- SUPPLY — PUSH
- DEMAND — PULL

Figure 13

A FEW MYTHS ABOUT INNOVATION

THE BETTER MOUSETRAP THEORY
TECHNOLOGY IS WHAT IT'S ABOUT
PATENTS ARE ESSENTIAL
PRICING "TECHNOLOGY TRANSFER" IS SIMPLE
INNOVATION IS BENEFICIAL

In any event, it is important to recognize that old saws often--usually--turn out to be myths where technology transfer and innovation are concerned. For example, necessity is not always the mother of either invention or innovation. Those with an inventory of technological possibilities to transfer had better be glad this is so. But they must galvanize the potential recipients of technology to want it--to see they are better off with it than without it--if they expect to succeed as parties to technology transfer activities.

There are still other myths about technology transfer and innovation. First, there is the too-well-known, too-widely-accepted, better-mousetrap theory. It is a myth, with rare exceptions. One can build the best of anything, but if people either do not know about it or do not have a need for it, it will not become a successful innovation. Far more than building a better mousetrap is involved. Reflect upon the earlier diagram describing the process of innovation. (Figure 9)

Another myth is that technology is what it is all about. It is not. Surely technology is there, by definition and by necessity. But especially for the private sector, what is most important is not the technology but the value that can be realized from exploitation of that technology.

Where do patents fit in all this? Put most simply, they certainly are neither necessary nor sufficient to drive an innovation process. They are part of the evidence of potential value in many cases, especially when technology transfer is involved, but they are not essential if the parties to the transfer and the managers of related innovation processes recognize patents for what they are and are not. The latter is often the more important: patents are not a warranty of suitability or practicality; they only support a claim that a technology is unique. To the extent such uniqueness imparts or enhances value, the patent helps. But even with a patent, there is no guarantee that a given technology will lead to a commercially successful innovation--or to innovation at all.

To indicate where patents fit in the process of innovation in another way, a study which carefully examines about 1,100 specific industrial processes of innovation in six industrialized nations did not find a single such process that was either held up or accelerated because there was a patent application in process or issued or desired. Patents simply do not seem to be on the critical path where most innovation processes are concerned. Does this mean the patent system should be abandoned? Certainly not. Patents do serve useful purposes, including many of those the founding fathers intended. It is simply that patents and the patent system have limitations, especially in the context of innovation.

It should be recognized that innovation is not always beneficial. The buggy whip manufacturer who stayed with buggy whips did not see the automobile as a beneficial innovation. (Figure 14) The innovation of nuclear weapons is not viewed universally as beneficial; neither is the mass-produced, really cheap Saturday Night Special. But a high propensity to innovate as a national characteristic is beneficial, even if some innovations are otherwise on closer and specific examination.

The process of innovation can also be understood through consideration of the inputs to and outputs from the process. (Figure 15) The inputs are numerous and some are obvious. Some are physical, some intellectual. Among the less obvious are the requirements that there be a perceived need for the product or service. Also, there must be not just management but a measure of entreprenuership which carries with it the ability to see the process for what it is, delineate objectives all the way through the process, marshall the essential resources, and galvanize all the people necessarily involved in the process if it is to be a successful one. And always, the resource of time is crucial.

For a firm, the outputs of technology transfer and innovation activities are also a mixture of "hard" and "soft" and of the obvious and not-so-obvious. (Figure 16) Innovation, being risky, can generate losses; profits are definitely not guaranteed. Visibility and image effects can also be positive or negative, depending upon specific circumstances. Always, a result of innovation processes undertaken are intellectual excitement and, as previously noted, risk.

So, what is for sale when a technology is put up for transfer to a private enterprise? (Figure 17) It is some quantum of technology; it

Figure 14

INNOVATION—“BENEFICIAL”

WHOSE BENEFITS COUNT?
AND HOW MUCH?

WHOSE COSTS COUNT?
AND HOW MUCH?

INNOVATION—“SUCCESSFUL”

WHAT CONSTITUTES “SUCCESS”?
HOW DO YOU KNOW WHEN YOU’VE WON?

ONE MAN’S SUCCESS IS ANOTHER’S DISASTER.

ONE MAN’S “MUNDANE” IS ANOTHER’S “INNOVATION”.

Figure 15

INPUTS TO THE INNOVATION PROCESS

CREATIVITY
BASIC RESEARCH (SCIENCE)
APPLIED RESEARCH
PERCEIVED NEED
DEVELOPMENT (R&D)
TECHNOLOGY
CAPITAL
MANAGEMENT, INCLUDING ENTREPRENEURSHIP
MANPOWER
INTELLECT
CRITICAL COMMENTARY
APPLICATION AND DEDICATION
REAL PROPERTY
TIME

Figure 16

OUTPUTS OF THE INNOVATION PROCESS

FOR THE ENTERPRIZE

- PROFITS
- LOSSES
- PATENTS
- VISIBILITY/IMAGE
- GROWTH
- FLEXIBILITY AND DIVERSITY
- EXCITEMENT
- RISK

Figure 17

WHAT'S FOR SALE?

- TECHNOLOGY?
- OPPORTUNITY?
- GLORY?
- THE HERO'S LIFE?

↓

<u>VALUE</u>: AN OPPORTUNITY TO EARN ATTRACTIVE PROFITS.

is a market opportunity; it is glory for the successful entrepreneur and his associates; it is even a hero's life with that implying anything one reasonably chooses--if the effort is crowned with great success. Above, all, it is value as manifest through the opportunity to earn attractive profits.

VALUING TECHNOLOGY

And how can it be recognized that a technology available for exploitation may have value? There are several ways. Some relate to patents--their existence and their having been tested and survived. Other aspects of a technology are easier to evaluate with precision, especially if a technology has been successfully employed in a different setting so that real market results are available. (Figure 18) In today's world, however, a technology which affords relief from present or anticipated materials shortages and those that may be needed to meet a safety or environmental regulation are seen to have special value which, of course, promotes their transfer and use.

Also note that job creation and job elimination are both evidences of value--usually to different parties to the transfer of technology. Private sector entities are most likely to seek technology and techniques that reduce labor content; governmental units at present are stressing job creation and improvement in the U.S. balance-of-trade position for good and valid reasons.

It is important to consider how value can be derived from a technology once value has been found to be present--at least potentially. First, it is important to understand something more about the structure of the overall industry where the technology may ultimately find a home. Consider aircraft manufacturing: myriad suppliers of goods and services feed the aircraft assembler which, in turn, addresses the airlines, aircraft lessors, and the government. Subsequently, these address their own customers such as, for the airlines, their passengers and shippers.

Given this set of vertical relationships, where do you most effectively promote a technology or an innovation? (Figure 19) First, it depends upon the particular technology or innovation--but not entirely. Suppose one has developed a new alloy with great high-

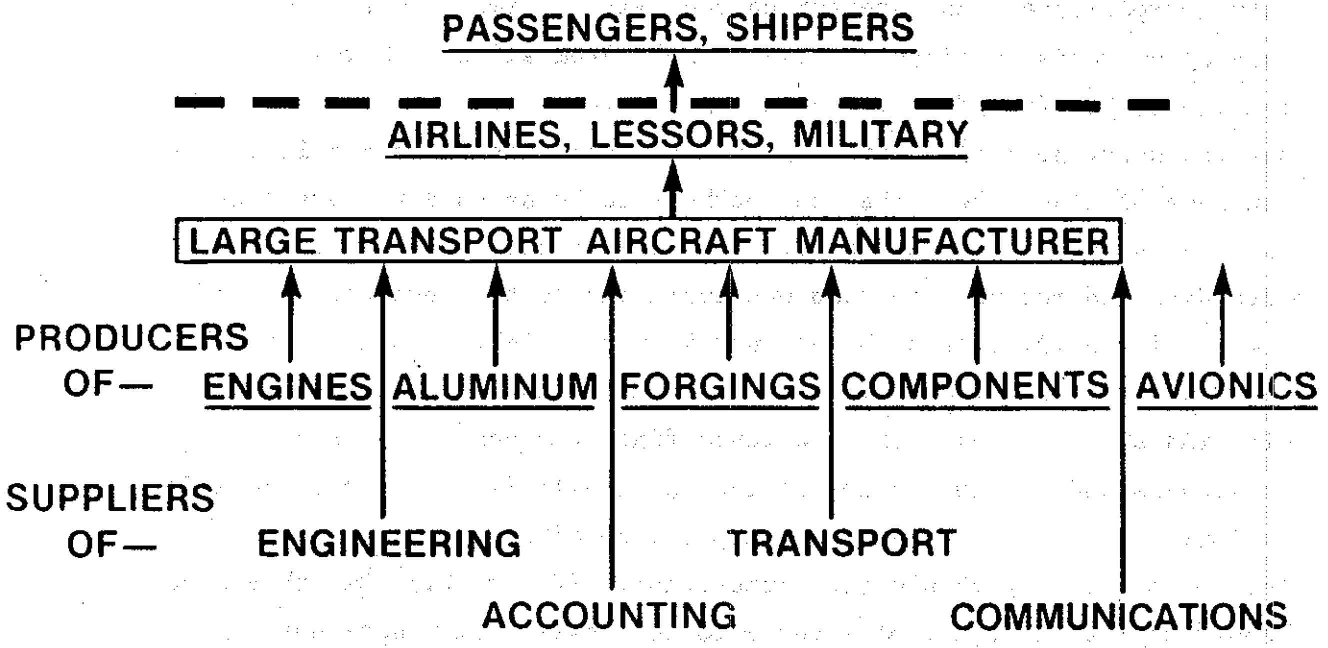
Figure 18

EVIDENCE OF VALUE IN A TECHNOLOGY

- PATENTS
- KNOW-HOW
- EARNINGS RECORD (REVENUES?/PROFITS?)
- MARKET SHARE RESULTS
- SUCCESSFUL MARKET DEFENSE
- SUCCESSFUL PATENT DEFENSE
- SCARCE MATERIALS RELIEF
- MEET A REGULATORY REQUIREMENT
- CREATE JOBS
- ELIMINATE JOBS

Figure 19

VERTICAL RELATIONSHIPS IN INDUSTRY STRUCTURE: AN EXAMPLE



temperature properties. Where do you start? Obviously an engine producer is a possible target, especially if having the innovative alloy will vault the engine-maker ahead of its competition. But perhaps that is not the best place to go and probably it is not the only one. Consider what can be referred to as the new golden rule: "He who hath the gold makes the rules." If there is an aggregated buyer of aircraft that can benefit materially from the new, more efficient engines, such a firm should be approached to bring some demand-pull power into play. In the present context, this might be a large and growing airline, but it is more likely to be the military. The point is that one always needs to analyze each specific situation before devising a strategy for transferring a technology and implementing it--thereby maximizing the value realized from its use.

This point is further stressed by another example drawn from actual experience. An inventor came up with an improved rockbolt (for holding up roofs in mines). (Figure 20) From all the choices available, he offered a license to the operator of a single mine. This was the worst possible choice, given the fact that there are literally hundreds of mines where the new rockbolt could be used to advantage. Clearly any other choice was better; the best one, however, required more data and information than was available to the inventor at the time, principally because he did not know the right questions to ask.

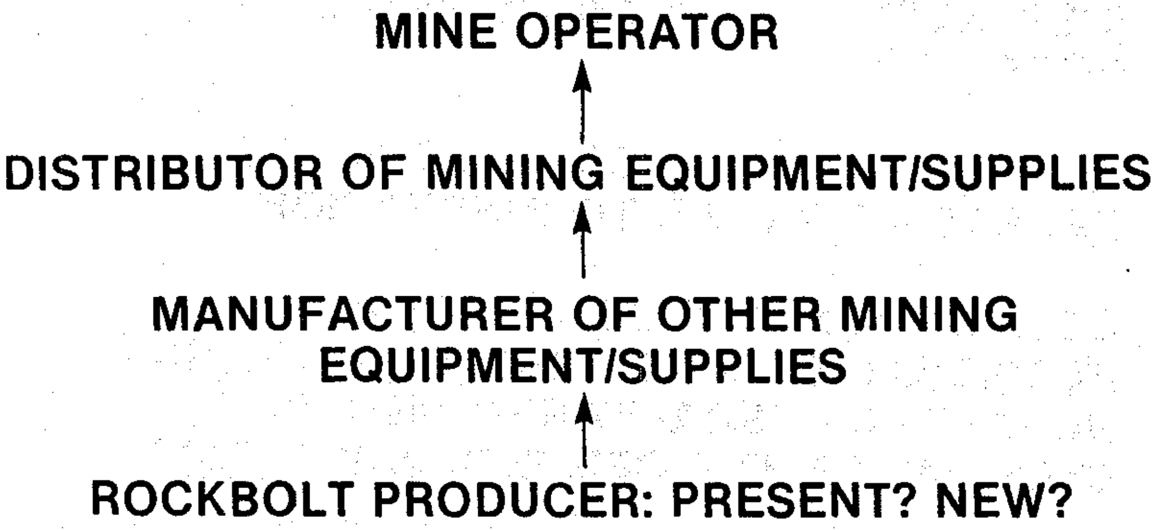
To derive maximum value from a technological possibility, those with industrial innovation experience find it essential to recognize and understand how such technological possibilities are generated and exploited. They know that technological possibilities are indispensable to technological innovation. (Figure 21) But they also know that the existence of a technological possibility does not guarantee that an innovation will result. Furthermore, substantial resources are required to convert technological possibilities into practical use, and among these resources is time.

The most effective processes of innovation have also been found to be market-specific. That is, the nature of the market the innovation is designed to address should directly determine the process of innovation itself. Moreover, in fields characterized by complicated

Figure 20

INDUSTRY STRUCTURE AND SELECTING A TARGET LICENSEE

THE IMPROVED ROCKBOLT



MINE OPERATOR

↑

DISTRIBUTOR OF MINING EQUIPMENT/SUPPLIES

↑

MANUFACTURER OF OTHER MINING EQUIPMENT/SUPPLIES

↑

ROCKBOLT PRODUCER: PRESENT? NEW?

Figure 21

RECOGNIZE AND UNDERSTAND (GENERALLY) HOW "TECHNOLOGICAL POSSIBILITIES" ARE GENERATED AND EXPLOITED

- "TECHNOLOGICAL POSSIBILITIES" ARE INDISPENSIBLE TO TECHNOLOGICAL INNOVATION.
- "TECHNOLOGICAL POSSIBILITIES" DO <u>NOT</u> NECESSARILY LEAD TO INNOVATION.
- CONVERSION OF "TECHNOLOGICAL POSSIBILITIES" INTO PRACTICAL USE (INNOVATIONS) USUALLY REQUIRES SUBSTANTIAL RESOURCES, <u>INCLUDING TIME.</u>
- INNOVATION IS MARKET-SPECIFIC BY DEFINITION.
- IN COMPLEX FIELDS (SUCH AS ENERGY, TRANSPORT AND COMMUNICATIONS) PROCESSES OF INNOVATIONS ARE OFTEN LINKED AND MORE THAN ONE "TECHNOLOGICAL POSSIBILITY" IS BEING PURSUED IN THE SAME CONTENT AND TIME FRAME.

production functions, innovations are frequently linked, with more than one technological possibility being pursued simultaneously. For example, as the railroads attempt to improve their efficiency partly through the introduction of innovative rolling stock, they are simultaneously attempting to pursue new braking and coupling innovations, both of which are necessary to achieve the desired objective.

So it is that to extract the benefits and values from technology transfer and innovation, sufficient motives must be present in the acquirer of the technology to cause him to take it. (Figure 22) Once such motives are manifest, the technology must actually be available--that is, the data and information that are essential to its transfer must be present and in the proper form, and above all, the people who know about the technology must be willing and available to transfer what they know to the licensee or buyer of the technology.

Of course, the technology must be made credible, and its relevance to one or more markets of interest to the buyer or licensee must be clearly established. And the price of the license or other arrangement relating to use of the technology must be right.

When seeking those likely to acquire technology--or to supply it, for that matter--the means of identifying them are not very surprising. But there are two very important points to be made nonetheless. (Figure 23) First, the open literature is no substitute for detailed and intimate knowledge of the markets into which an innovation based upon a given promising technology is likely to be introduced. Such knowledge, supplemented by widespread personal contacts, is crucial to successful transfer in most cases. Second, it is essential to recognize that smaller firms are disproportionately the hotbeds of technological innovation activity in the United States. (Figure 24) These must not be overlooked. Quite the contrary: they should be sought out. The chances of successful technology transfer are higher for many technologies where small firms are approached as compared with large ones. Of course, there are those technological possibilities that only large-scale enterprises can exploit, but generally, small firms are the more willing recipients of externally-generated technological possibilities.

Figure 22

TO REALIZE THE BENEFITS AND VALUES FROM TECHNOLOGY TRANSFER, REMEMBER THE PRE-CONDITIONS FOR THE SALE OR TRANSFER OF TECHNOLOGY

—MOTIVE(S) PRESENT IN BUYER/TRANSFEREE
—AVAILABILITY OF THE TECHNOLOGY
—CREDIBILITY OF THE TECHNOLOGY
—RELEVANCE OF THE TECHNOLOGY

. . . AND THE PRICE MUST BE RIGHT

Figure 23

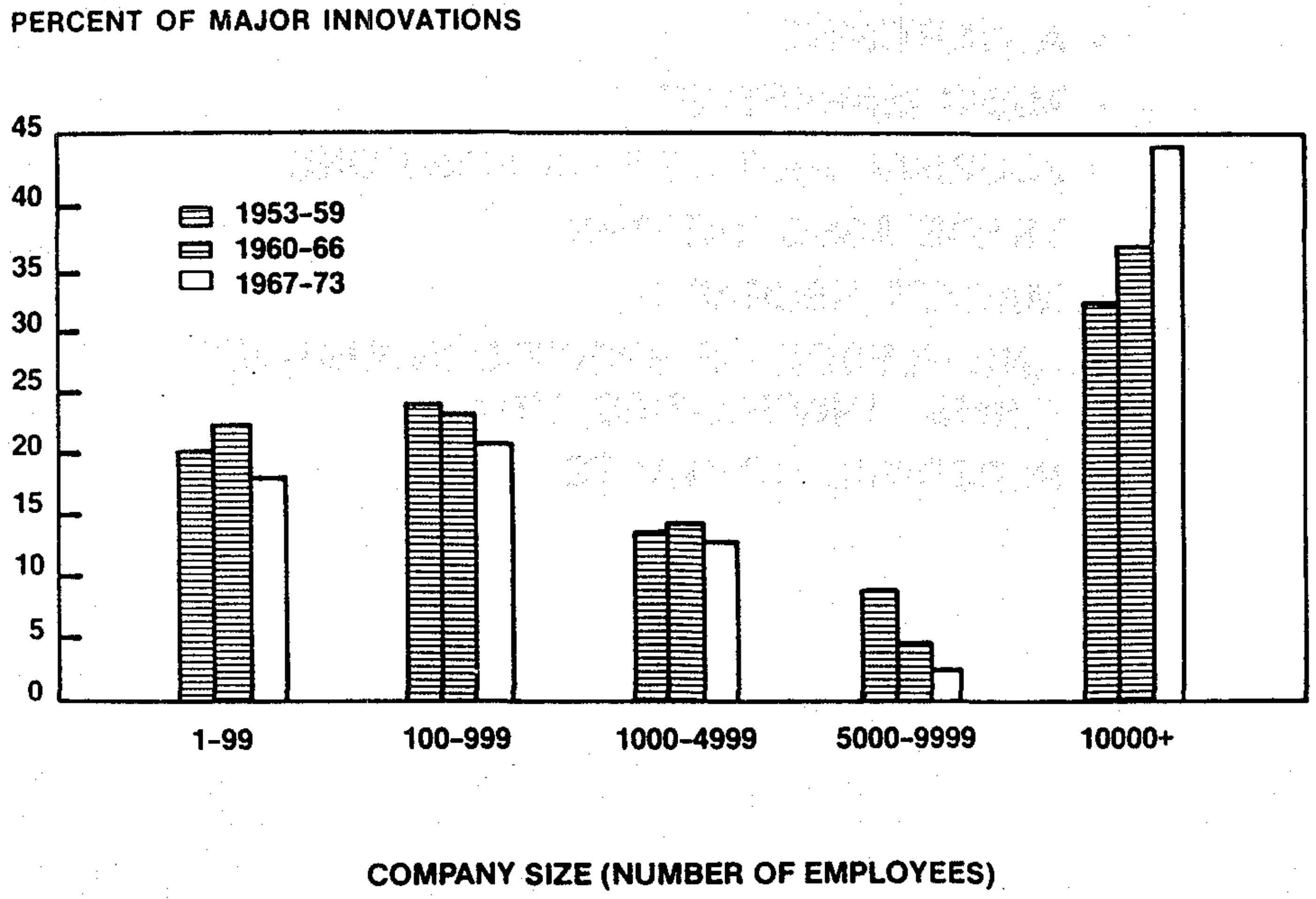
IDENTIFYING TRANSFERORS AND TRANSFEREES

- ADVERTISING
- MASS MARKETING
- JOURNAL ARTICLES OR MENTIONS
- TRADE ASSOCIATIONS
- MARKET RESEARCH
- KNOWLEDGE OF SPECIFIC INDUSTRIES, FIRMS, UNIVERSITIES, ETC.
- PERSONAL CONTACTS

Gellman Research
Associates, Inc.

Figure 24

DISTRIBUTION OF MAJOR U.S. INNOVATIONS, BY SIZE OF COMPANY, 1953-73



Source: GRA for N.S.F.

RESISTANCES AND BARRIERS

There are myriad resistances to technology transfer and innovation. (Figure 25) Some are general attitudinal resistances; others are more rational, though often wrong-headed. It has already been noted that resistance often grows out of a need for systems integration in order for a technology to be usefully employed. For example, if use of a new solid-state device requires changing a much larger range of hardware or software or both, it is much more difficult to innovate successfully as contrasted with the situation where the device represents a stand-alone innovation. Again, if an innovative product results in the obsoleting of present capital investment still on the books with the necessity to take a book loss--something businessmen are usually loathe to do--there will be great resistance to the innovation, although it may well not be thwarted, especially if its adoption serves to enable a new entrant to break into a lucrative market. And, as noted before, market structure extremes create resistance. But perhaps the most widespread and pernicious force against innovation has to do with businessmen's frequent over-avoidance of risk. Often they fail even to make the appropriate risk-reward calculations, rejecting innovative ideas and products out-of-hand.

Other barriers to the transfer of technology are present on both the demand and supply sides of the equation. (Figure 26) Suppliers of technology--such as Federal laboratories--have rarely had a program of licensing or other mechanisms to promote and support technology transfer. Sometimes this may reflect a lack of appreciation of the value that their technology can realize through transfer. Again, there may be insufficient or inappropriate documentation for attracting potential buyers of the technology. In the case of the private sector, possibly the firm is lacking a well-enough-developed profit orientation. An inadequacy of personal incentives to company executives to transfer technology at a profit can also account for some failures, as can over-emphasis on the legal fine points.

Buyers of technology erect both the same and different barriers to the transfer of technology. One especially powerful negative force which is unique to buyers is the infamous not-invented-here (NIH)

Figure 25

MAJOR RESISTANCES TO TECHNOLOGY TRANSFER AND INNOVATION

- GENERAL RESISTANCE TO CHANGE
- NEED FOR SYSTEM INTEGRATION (AS CONTRASTED WITH STAND-ALONE)
- WHERE CAPITAL LOSSES WOULD RESULT (OBSOLESCENCE)
- UNCERTAINTY OR PAUCITY OF DATA — BOTH TECHNICAL AND DEMAND
- OVERAVOIDANCE OF RISK
- MARKET STRUCTURE EXTREMES ("PURE" MONOPOLY OR "PURE" COMPETITION)

Figure 26

BARRIERS TO THE TRANSFER OF TECHNOLOGY

POTENTIAL SUPPLIERS OF TECHNOLOGY

- LACK OF MECHANISM FOR TRANSFER
- NO APPRECIATION OF VALUE OF THE TECHNOLOGY IN THE TRANSFER "MODE"
- DEFICIENCY OF DOCUMENTATION
- INSUFFICIENT PROTECTION (E.G., PATENT, MARKET EXCLUSIVITY)
- ABSENCE OF A PROFIT ORIENTATION
- PRICE TOO HIGH
- INSUFFICIENT RESOURCES ALLOCATED TO TECHNOLOGY TRANSFER
- INADEQUATE PERSONAL INCENTIVES
- OVEREMPHASIS ON THE LEGAL

POTENTIAL RECIPIENTS OF TECHNOLOGY:

- NOT-INVENTED-HERE (NIH) ATTITUDE
- NO APPRECIATION OF THE VALUE OF THE TECHNOLOGY
- LACK OF KNOWLEDGE OF THE MARKET(S) INVOLVED
- INSUFFICIENT PROTECTION
- PRICE TOO HIGH
- INSUFFICIENT CAPITAL TO EXPLOIT THE TECHNOLOGY
- INADEQUATE INCENTIVES TO ASSUME RISK
- TOO MUCH FINANCIAL SUCCESS
- OVER-SPECIALIZATION
- OVEREMPHASIS ON THE LEGAL

attitude. This is all too common in modern society and may represent the most significant single barrier to technology transfer. But there are others as enumerated in the accompanying list.

To overcome all of these barriers, relevant and comprehensive data and information are critical. (Figure 27) There can hardly be too many data, too much information. Scientific data, performance data, market data, and economic data are all helpful, and some are indispensable. Such material can be generated in laboratories, from the exercise of prototypes, through feedback from an actual operating environment, and as a result of market projections and analyses which are thoughtfully made.

INCENTIVES AND DISINCENTIVES

The incentives and disincentives that influence individuals and organizations where technology transfer and innovation are concerned must be taken into account. (Figures 28 and 29) The "people" nature of such activities is clearly reflected in what motivates individuals, either positively or negatively. The incentives include such expected stimuli as increased current income or heightened future income or both. Also there are possible non-salary benefits such as stock options and travel. Job promotion often becomes more likely through association with successful innovation processes. And increased personal prestige and professional responsibility may well follow. Also, of course, job offers might emerge.

The shop rights incentive is especially interesting and has been employed in a limited way in the private sector and also by the U.S. government on occasion. (Giving an employee shop rights means that the employee can derive benefits directly from the licensing or sale of "his" technology to organizations or firms beyond the one for which he worked when the invention or scientific outcome was realized.) In addition, one of the more powerful motives for some persons is to be allowed to participate in the application of their own ideas or inventions whenever they become the bases for specific innovation processes.

Figure 27

DATA AND INFORMATION REQUIREMENTS TO SUPPORT TECHNOLOGY TRANSFER

- IS SCIENTIFIC DATA ENOUGH?
- SCIENTIFIC DATA PLUS PERFORMANCE DATA?
- MARKET DATA?
- ECONOMIC DATA?

* * * * * * * * * * * * * * * * * *

LABORATORY-GENERATED MATERIAL
ROLE OF THE PROTOTYPE(S)
TEST RESULTS
SPECIFICATIONS AND PERFORMANCE
FEEDBACK FROM THE OPERATING ENVIRONMENT
COSTS — CAPITAL AND OPERATING
RELIABILITY DATA
INTENSITY AND LONGEVITY OF USE
MARKET PROJECTIONS AND ANALYSES

Figure 28

INCENTIVES TO INNOVATION THAT INFLUENCE THE INDIVIDUAL

1. INCREASED CURRENT INCOME
2. INCREASED FUTURE INCOME
3. NONSALARY "PERKS" OF VALUE (E.G., STOCK OPTIONS, PROFESSIONAL TRAVEL)
4. JOB PROMOTION OR HEIGHTENED PROBABILITY OF PROMOTION
5. INCREASED PRESTIGE AND/OR RESPONSIBILITY
6. JOB OFFERS
7. SHOP RIGHTS
8. OPPORTUNITY TO PARTICIPATE IN THE THE APPLICATION OF ONE'S OWN IDEAS OR INVENTION

Figure 29

DISINCENTIVES TO INNOVATION THAT INFLUENCE THE INDIVIDUAL

1. LACK OF REWARDS, EVEN IF "SUCCESSFUL"
2. INCREASED VISABILITY
3. INCREASED RESPONSIBILITY
4. EXTRA EFFORT REQUIRED TO PERFECT THE "INNOVATION"
5. LIKELIHOOD OF JOB CHANGE (E.G., NEW RESPONSIBILITIES AND/OR GEOGRAPHICAL SHIFT)
6. FRUSTRATION (E.G., INABILITY TO ADVANCE A "GOOD IDEA")
7. RISK OF FAILURE
8. EMPLOYER ATTITUDE TOWARD FAILURE OF AN INNOVATION PROCESS

The disincentives playing upon an individual can be the very same ones that were cast as incentives just above. Some people want visibility and prestige, some absolutely shun both. One man's meat is another's poison. Beyond this, note some of the other unalloyed disincentives. If an employer is unlikely to take advantage of an employee's good idea, the latter certainly is discouraged from making it known and subsequently suffer frustration and rejection. If an employer views every failure as a catastrophe and acts accordingly, an employee is once more discouraged from undertaking anything with significant risk.

The incentives and disincentives facing a firm include some that were present on the level of the individual. (Figures 30 and 31) Others obviously are different. Among the more interesting positive forces are those related to the achievement of various corporate goals and objectives. Several other incentives and disincentives operating at the level of the firm were referred to earlier. All are more of less important and powerful depending upon the specifics of the technology transfer or innovation process upon which they bear.

PRICING TECHNOLOGY TRANSFER

Pricing is obviously of great importance when technology transfer is at issue. (Figure 32) Many believe the pricing of a technology in the context of transfer is a simple matter, whether it be through a license or outright sale of the technology. Is it?

First, is pricing technology an "art" or a "science"? There are several theories about how a technology "should" be priced. For example, many who ought to know better hold that the price a technology should command directly reflects either the cost of having generated the technological possibility or the cost the potential buyer of the technology would have to incur to get to the same point. Does such theory accord with reality? Not often, and then only where the present discounted value of the technology in the hands of the buyer, factored liberally for risk, accidently matches one of the previous magic numbers. Again, it is value that should have center stage, not the cost of generating a technological possibility.

Figure 30

INCENTIVES TO INNOVATION THAT INFLUENCE THE FIRM

1. INCREASED CURRENT EARNINGS
2. INCREASED FUTURE EARNINGS
3. ACHIEVEMENT OF REVENUE GROWTH OBJECTIVES
4. ACHIEVEMENT OF PROFIT OBJECTIVES (E.G., REDUCE COSTS, STIMULATE DEMAND)
5. ACHIEVEMENT OF CORPORATE DIVERSIFICATION OBJECTIVES
6. INCREASED MARKET SHARE
7. INCREASED MULTIPLE ON STOCK
8. CAPITAL CONSERVATION (E.G., PROMOTE NON-CAPITAL-INTENSIVE PRODUCTION METHODS)
9. REDUCED DEPENDENCE ON LABOR
10. AVAILABILITY OF IR&D FUNDS
11. MEET REGULATORY REQUIREMENTS
12. PRESENCE OF REGULATION THAT HEIGHTENS THE PROBABILITY AND/OR PROFITABILITY OF SUCCESSFUL INNOVATION
13. IMPROVE RECRUITMENT RESULTS
14. ENHANCED IMAGE

Figure 31

DISINCENTIVES TO INNOVATION THAT INFLUENCE THE FIRM

1. INSUFFICIENT COMPETITIVE SPUR
2. RISK OF CAPITAL LOSS
3. CAPITAL SHORTAGE
4. SHORT-TERM EARNINGS PENALTY
5. INSUFFICIENT PERIOD OF "MONOPOLY PROFITS," EVEN IF SUCCESSFUL
6. SUFFICIENTLY HIGH RETURNS AND GROWTH RATES WITHOUT ASSUMING THE RISK OF INNOVATION
7. DURABILITY OF CAPITAL EQUIPMENT ON HAND
8. INELASTIC DEMAND FOR CURRENT PRODUCT(S) OR SERVICE(S)
9. RATE-OF-RETURN REGULATION EMPLOYING A DEFERRED RATE-BASE CALCULATION
10. TECHNOLOGICAL INTEGRATION (E.G., "LUMPINESS" OF INVESTMENT NEED TO FIT INTO TECHNOLOGICALLY COMPLEX SYSTEM)
11. REGULATION—ECONOMIC OR OTHER
12. ANTITRUST IMPLICATION OF INNOVATION
13. INDUSTRIAL STANDARDIZATION (EXTERNALLY OR INTERNALLY IMPOSED)
14. LACK OF CORPORATE/DIVISIONAL GROWTH OBJECTIVES
15. RISK OR FEAR OF "FAILURE"
16. INAPPROPRIATE REWARD STRUCTURE TO PROMOTE INNOVATION

Figure 32

PRICING "TECHNOLOGY"

- IS IT "ART" OR "SCIENCE"?
- THEORY VS. REALITY
- VALUE AND COST
- DECISION TAKEN AT THE POINT OF MAXIMUM IGNORANCE
- WHAT IS BEING SOLD?
  - THE "TECHNOLOGY"
  - THE TERRITORY
  - THE END USES
  - THE MARKET POSITION
  - THE TIME FRAME

Note, too, that pricing negotiations and decisions almost always are taking place at, or close to, the point of maximum ignorance of the parties to the transfer. The seller fears to disclose too much about its technology and give away the store; the buyer does not want to indicate the full range of uses it sees for the technology lest the price be raised. So pricing is difficult on these grounds alone.

But that is not all: what is actually for sale? By now it should be clear that it is value growing out of opportunity. But to estimate this value, it is necessary to specify such boundaries on the sale of technology as the geographical territory involved, the end uses to which the technology may be put (if they are to be limited), the market access decision (exclusive? non-exclusive?), and the duration of a license if this is the transfer mechanism involved.

While all this is being contemplated, it is well to keep in mind something of the nature of the cost structure of the usual industrial innovation. (Figure 33) Careful analysis of many industrial innovation processes in various capitalist nations supports the conclusion that, in general, the research and development phase of a process consumes about 10 percent of the total resources required to bring an innovative product or service to market. Technology delivery--the production and marketing phases together--require the other 90 percent of the resources. So it is that a technology available for transfer--especially if it comes out of a laboratory--is very often little more than an R&D outcome; consequently, the recipient of that technological possibility may well have actually imposed upon itself a need to expend a very great amount of money to convert what was received into an innovation.

The very dimensions of price where technology transfer is contemplated are numerous and can be complex. (Figure 34) They range from a simple once-for-all front-end payment for a defined technological possibility, to a combination of payment bases with resultant compensation for the supplier of the technology depending upon various factors. Specific elements of price can include such diverse approaches as straight royalty and a requirement that the licensee buy parts or products from the licensor as a condition of the transaction. And, of

Figure 33

COST STRUCTURE OF INDUSTRIAL INNOVATION

RESEARCH & DEVELOPMENT PHASE	~10%
PRODUCTION PHASE	~90%
MARKETING PHASE	

Figure 34

DIMENSIONS OF PRICE

- ONCE-FOR-ALL FRONT-END
- FRONT-END PLUS PARTICIPATION
- ROYALTY-ONLY (RATES?)
- MINIMUMS
- EXCLUSIVITY
- GRANT-BACK
- TECHNOLOGY TRADING AND CROSS LICENSING
- IMPROVEMENTS
- PURCHASE OBLIGATIONS
- COMBINATION PAYMENT ARRANGEMENTS

course, such issues as minimum royalties, the nature of any exclusivity provisions, and possible cross-licenses also spice up the negotiations!

There are a number of other pricing issues to be considered when technology transfer is afoot. One of the more interesting has to do with grant-backs. The licensor, for example, can seek to include in the price of the technology a requirement that the licensee grant back any improvements it may make in the original technology. This is one dimension of price. And it can be all the more complicated if the licensee seeks compensation for the use of granted-back improvements from the original developer or source of the technology.

Also to be recognized is that there often are recurring costs for the seller of a technology unless there is an entirely "clean" all-up-front deal--which is a rarity. Such continuing costs include those associated with auditing any royalty payments and trouble-shooting consulting associated with the use of the licensed technology and techniques. (Figure 35)

Another issue is simple to state but not so simple to resolve: What is the seller of a technology seeking to maximize through the price being asked? Even if its goal is entirely monetary, near term and long term income have different values for different people or firms. Therefore, present-valuing the expected stream of funds is critical to deciding both the level and structure of the several components of the price being established for a technology.

So is pricing technology an art or a science? Can there be any doubt? There are elements of science in that some supporting calculations are more or less precise but, in the end, much art enters and actually drives the ultimate pricing result in the great majority of cases.

It may help to underscore this point by noting the difference between optimizing and "satisficing." The latter is a made-up word; it was created by Professor Herbert Simon of Carnegie Mellon University who won the Nobel Prize in Economics primarily for this concept. Fundamentally what Professor Simon enunciated and proved is that many businessmen do not, in fact, perpetually pursue the optimum solution to each of the problems which they face. They are not always long-run

Figure 35

SERVICING THE LICENSE

- COSTS AND BENEFITS
- CONSULTATIONS AND VISITATIONS
- DEMONSTRATIONS
- DATA AND INFORMATION
- RELEVANCE TESTS
- ESTABLISHING AND MAINTAINING CREDIBILITY

profit-maximizers. Very often they merely seek a satisfactory solution--they "satisfice." The points are that what constitutes the optimum stream of income and other benefits associated with the sale or license of a technology is extremely difficult to determine and that those who price technology should recognize they are dealing more in art than science. They must do the best they can and not agonize if they are unable to squeeze the very last nickle out of the technology when it is transferred. Moreover, since most technology licensing and other transfer arrangements have a time dimension, the further the delay in consumating a transaction because of some attempt to optimize the return, the later the income stream actually begins, thus reducing the present value of the arrangement. Satisficing, then, suggests making reasonable compromises to enable the technology transfer to take place--and to do so sooner rather than later.

SUMMARY

Summing up with regard to technology transfer can best be accomplished by asking "What is being sold when technology is on the block?" For industry, the answer clearly should be a "value born of opportunity and not technology *per se*." Also, it should be clear that in seeking to move a technology from one setting to another, no potential recipients will respond to the opportunity if the existence of the technology is unknown to them. But that is not enough; the technology that is being offered must be made relevant to the buyers' needs and their own objectives, which generally requires a "market relevance statement" for the technology.

Insufficient data and information about a technology may well prevent its being credible to potential customers, and in any case, they will not be particularly interested if the technology cannot be replicated and exploited in their own settings. So, among other things, appropriate data and information about each technology are clear prerequisites to their sale or transfer. And, of course, the price must be right.

Issue Paper IV

COOPERATIVE RESEARCH AND THE PRIVATE SECTOR

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Gulf South Research Institute

Cooperative research is emerging in the United States as an experimental mechanism for enhancing industrial innovation. The term "cooperative research" refers to the use of joint resources (e.g., funds or personnel) to conduct research of mutual interest and benefit to the participating parties. The participants can be industries working together or industries and public institutions operating through a Cooperative Research Center or under a research agreement.

Most R&D is conducted in industrial laboratories, universities, and Federal laboratories. Traditionally, the U.S. research community has tended to be fragmented and specialized, operating in separate realms and concerned with different objectives. University and Federal laboratory personnel perform most of the Nation's basic research, with applied R&D work conducted primarily by industrial scientists and engineers. Interchanges occur through the transfer of personnel and students, the published literature, conferences, and informal contacts between individual researchers.

In the last decade, the public and private sectors have become increasingly interested in opportunities for closer working relations among the members of the national research community to improve U.S. industrial growth and competitiveness. Cooperative research arrangements is one of the mechanisms available that offers a vehicle for transferring technology from the Federal laboratories to the private sector. The primary benefit of cooperative research efforts is that an on-going relationship with firms can be established early in the innovation process, prior to development of laboratory technology. Private sector firms not only provide research funding, but technical and market perspectives that are essential to successful transfer efforts.

The purpose of this paper is to examine: (1) the economic and technological environment that is encouraging cooperative research activities; (2) types of cooperative arrangements; (3) industrial motives for participation and expected outcomes; and (4) implications for Federal laboratories.

ENVIRONMENT FOR COOPERATIVE RESEARCH

The concept of cooperative research is not new. Historically, industrial and academic researchers have worked jointly to accomplish specific objectives. The National Bureau of Standards was formed to set standards and provide testing services with the assistance of a wide variety of industrial groups. The two most common examples of large-scale national cooperative efforts yielding impressive results are the Manhattan Project and the Apollo Project. Both projects had specific technical objectives and required the commitment of significant personnel and financial resources from the private and public sectors. Both required the talents of basic and applied researchers working in numerous fields simultaneously and impressive organizational skills to coordinate and integrate the various developments. Research results from both efforts produced technology that was applied in the industrial and commercial sectors.

Just as these massive efforts were undertaken in response to intense international competition in the military and political realms, the present interest in cooperative research is prompted by competitive pressures in the economic realm. A second and equally important factor is the rapid advance of technology fundamental to the development of new and improved products, processes, and services.

Economic Growth and Technology-Based Innovation

Much of the technology that gave rise to new industries and tremendous economic growth in the United States was created in the 19th century. The U.S. economic performance has been based on the successful introduction of new products and services. Equally important, new processes and production techniques were required to mass produce high-quality manufactured products to create and serve growing national markets. Key basic industries developed and concentrated on volume production requiring standardization of both the products and the processes used to make them.

The economy is now undergoing profound changes. Two of the most important are: (1) the emergence of a global economy; and (2) the increasing influence and importance of technology to economic growth, not only in the United States, but in all industrialized nations.

Following the U.S. model of economic success, other nations are relying on technology (often obtained in the United States) to increase their economic performance and are concentrating on advanced production techniques to increase their competitiveness. In fact, technology (new and old) may be becoming a strategic variable as important as human and financial resources for individual firms and governments. Foreign firms are now producing many products that were once supplied by U.S. firms and are also exporting these products to many markets, including the United States. The United States is the world's largest and most lucrative market and naturally attracts foreign firms.

The effects of these developments on key basic industries and the U.S. economy as a whole are apparent. Industrial firms are faced with the need to protect domestic markets from foreign competitors and must also compete in expanding international markets as a method of sustaining economic growth. The petrochemical industry faces increasing competition in commodity products from Mexico, the Middle East, and the Soviet Union. European firms are competing effectively in the aircraft industry. Dramatic successes by the Japanese in penetrating U.S. and international markets in the steel, automobile, and shipbuilding industries and consumer electronics are well known. As the European and Japanese models of developing or adapting technology are continued and replicated by other nations (e.g., Korea), pressures from foreign competition can be expected to continue and to increase.

U.S. economic indicators show a decade of declining exports in all manufacturing sectors, increased imports in many sectors, and large trade deficits for manufactured goods. Workforce productivity is declining relative to other industrialized nations, and large firms are not only laying off many workers, but have not created any new jobs (net) since 1980. Some commentators (e.g., Robert Reich, "The Next American Frontier," <u>The Atlantic Monthly</u>, March 1983, pp. 43-58) lay much of the blame on American management, particularly the propensity to focus on short-term profits rather than longer-term technological strategies.

Because of the critical nature of the economic situation, Congress has focused its attention on new and largely experimental measures in the areas of U.S. economic growth, industrial innovation, and international competitiveness. In the discussions of these areas at the national and state levels, cooperative research emerges as an important element. These discussions contain several assumptions about the relationship of research and technology to innovation and economic growth, which form the basis for understanding the context, purposes, and expectations of cooperative research activities:

1. The continued growth of the economy is strongly related to the innovation process.
2. The innovation process requires the continuous introduction of new and improved technology in the form of both products and processes.
3. U.S. industries are experiencing competitive pressure (particularly from the Japanese) as a result of technological innovation.
4. U.S. firms accounting for significant growth and job creation are primarily small, innovative, and technology-based.
5. High-growth technology-based firms employ highly technical personnel and allocate a large percentage of revenues to R&D efforts.
6. Research is important to technological advancement and innovation.
7. Japanese (and European) accomplishments are possible partly because of government subsidies in technological research and development and cooperative research efforts among larger firms.
8. The Federal laboratories have facilities, equipment, and personnel that could make significant contributions to U.S. industrial innovation and international competitiveness.
9. Previous cooperative research efforts between government and industry have been successful (e.g., Manhattan Project and Apollo Project).
10. Opportunities for increased public (Federal laboratories and universities) and private sector cooperative research efforts

could contribute to increased technological innovation and strengthen the U.S. industrial competitive position.

Advancing Technology

The second major factor influencing increased interest in cooperative research is the current state of technological advance. Peter Drucker (in Technology Management and Society, Harper and Row Publishers, 1977) predicts that the explosion of new technology that occurred in the late 19th century will be matched at the close of the 20th century. Certainly, some of the major elements of this predicted explosion have already begun to appear, and the technical infrastructure is in place to continue and increase the level of scientific and technological advances. Three key aspects of technological advance need to be considered in relation to cooperative research: (1) the increasing importance of science to technology; (2) trends in product life cycles; and (3) the appropriability problem.

Science and technology are becoming much closer than they have been in the past. The second major technological explosion is likely to be as much science-based as technology-based in terms of the type and breadth of research that is necessary in several important fields. This development greatly enhances opportunities for cooperative research between scientists and technologists.

Biotechnology is a primary example. This emerging new industry originated in university laboratories and is a result of key scientific breakthroughs. Although the commercial successes of the first new companies have been relatively limited, the industry unquestionably holds great promise for new products that will dramatically affect the chemical, pharmaceutical, and agricultural industries. However, much work (both basic and applied) must be accomplished before the potential for commercial products and services can be realized. Repeating the successful strategy for microelectronics, Japanese firms are already concentrating major efforts on production techniques for biotechnology-based products.

Some of the major investments in industry-university cooperative research arrangements have been made in the biotechnology field. Many chemical and pharamaceutical companies are participating in cooperative research efforts. For example, Monsanto has made significant research investments at Washington University and Harvard Medical School.

Biotechnology is certainly not the only example of the increasing integration of scientific and technological work needed in relatively new fields that present enormous commercial potential. Communication systems, computer-integrated systems, very-large-scale integrated circuits, artificial intelligence, supercomputers, and new composite materials are all areas in which the leading edge of science and the cutting edge of application are merging.

Another aspect of the impact of advancing technology to consider is the argument that technology is advancing so rapidly that the average life span of "high tech" products (mainly in reference to computer technology) is decreasing rapidly, with some becoming obsolete in as little as three months. Continuous R&D is needed to keep pace. Consequently, high-tech companies (including startups) must invest large sums in R&D efforts. In industries where the development of base technology offers many potential applications, cooperative research may provide a cost-effective alternative to conducting inhouse research.

More importantly than shortened product life cycles, it is apparent that the realm of technology in certain areas is rapidly expanding. There are numerous avenues that can be pursued, and they are continuously unfolding in many scientific disciplines and through the work of many scientists and technologists in firms. In addition, it appears that in periods when key breakthroughs occur that lead to significant base technologies (e.g., microchips and gene-splicing), potential applications and approaches to product development are pursued along many diverse avenues, causing tremendous activity and creating extraordinary research and commercial opportunities. The industry's technology is not well defined or concentrated; it is still emergent and sources of technology are diverse. In these circumstances, it becomes much more important to pursue many avenues simultaneously--not only to advance the state-of-the-art, but simply to keep up with what others are doing. The expanding realm of technological development in many areas at the same time tends to encourage cooperative research activities as a method of increasing access to important base technologies and research capabilities that may exist outside the firm.

The third important aspect of advancing technology that favors participation in cooperative research efforts is rooted in the problem of appropriability, for which Frank Berardino provides a thoughtful discussion (in Briefing Book: Cooperative Research Ventures, Gellman Research Associates, 1984). The theory of appropriability maintains that whenever a high proportion of a technology is knowledge-based (as opposed to being a function of a unique mechanical, chemical, or electrical discovery or device), innovators will find it difficult to fully capture the financial benefits of the R&D investment.

In order to recover its R&D investment, the innovating firm must maintain a sufficient degree of control over the resulting technology and its applications. In many cases, control can be maintained by patents. However, when a technological field is rapidly advancing, it becomes very difficult to maintain control of knowledge-based technology and alternative strategies may be necessary. Advancing areas often require substantial R&D investments to keep up with other competing firms. At the same time it is quite likely that the resulting product and perhaps the underlying technology will become obsolete very rapidly.

Under these circumstances, a firm is faced with a dynamic situation requiring strategic decisions. The fundamental issue is whether to protect the long-term value of the technology by patents (i.e., disclosure) or to secure short-term financial benefits by maintaining internal secrecy for as long as possible and focus efforts on capturing market share as quickly as possible. When the technological field is advancing rapidly, the second alternative is often selected because the time and cost of patenting technology that has a short life span cannot be justified. It then becomes much more important to concentrate resources on marketing efforts. By capturing market share, an innovating firm can recover its investment by establishing itself as a technological leader, producing high quality, high-priced, high-profit products. This is a workable strategy because with knowledge-based technology, even patents may not provide sufficient protection, as products can be reverse engineered and redesigned to circumvent the patent. As imitators emerge, driving the initial price down, the technological leader introduces new products, maintains market share and high profit margins, thus repeating the cycle that allows the firm to invest in R&D and to recover its investment.

As Berardino (1984) observes, the <u>effects</u> of the problem apply to all firms dealing with knowledge-based technology. Appropriability works both ways to the detriment of the innovating firm. The innovator is unable to appropriate all of the fruits of its R&D effort; and competitors are able to appropriate by imitation what has been developed at another's expense.

Because of the appropriability problem, it is reasonable for firms to engage in cooperative research with competing firms and other research organizations to reduce their financial risk. State-of-the-art technological R&D often requires massive investment to move the technology to the next generation. When several firms are engaged in this type of research and there are many potential applications of an important base technology, and ownership of base technology patents may not be necessary, an opportunity for cooperative research emerges. The purpose of the cooperative effort is to continue to advance the technological area and reduce financial risk by combining resources with other firms or organizations working in the same general areas. The financial investment is leveraged most effectively at the pre-competitive stage where the expected outcome is the most uncertain--basic research. The prime criterion for participation in cooperative research then becomes (as the term implies) that each of the participants bring knowledge and capabilities of equal value into the venture. A neutral territory, as well as access to basic research capabilities, is then required. The research results can be shared by all of the participants because of the nonproprietary nature of basic research and its broad applications. The ways that the research results may be used by the firm to enhance its competitive position are maintained as proprietary information within the firm.

The appropriability problem in large part allows the kind of cooperative activity that occurs in these endeavors in a way that would not be possible, or necessarily desirable, except for the present state of base technology advancing faster than any single firm (or even a group of firms) can fully exploit in producing commercial products.

Silicon Valley serves as an example. Basically, a core group (or critical mass) of people with adequate knowledge was built up in Silicon Valley over 20 years. These people saw commercial opportunities based on R&D they were conducting. In many cases, the products did not fit in with company strategy, and often the technical person left to join another firm or to become an entrepreneur, thus creating "spinoff" firms. Many firms in the area, such as Hewlett-Packard and others, actively encouraged these activities. One reason may be that it was impossible for a single firm to capture all of the benefits because the range of opportunities that could be pursued was too large.

Many of these firms use know-how licenses to recover high R&D costs, open new markets, and acquire cash (often from larger companies) for growth. A high level of know-how licensing and the extensive intra-firm movement of engineers in the early days of Silicon Valley may reflect the relatively short supply of people who understood the base technology, the vast array of opportunities for new products created by the base technology, and the effects of the appropriability problem.

Recently several firms have formed cooperative research consortia operating at the pre-competitive stage. The Semiconductor Research Consortium contracts basic research to universities and the Microelectronics and Computer Technology Corporation conducts inhouse basic research of interest to its members.

OVERVIEW OF COOPERATIVE RESEARCH ACTIVITIES

A variety of interactions are occurring among industrial firms and between firms and public institutions. The various types of arrangements are distinctive, and it is important to understand the differences, similarities, and expectations that characterize each of them. Although some models have emerged, the content of the arrangements is still highly experimental. Each collaborative effort should be approached from the perspective that there is no one "right way" and that the important thing to consider is that the needs and capabilities of all of the participating parties should be fully understood at the outset. A program can then be developed that is compatible with those capabilities and expectations.

Generally, the type of cooperative research activity that is selected by an industrial firm appears to be directly related to one or more of the following factors:

1. A high level of scientific and applied research is needed to compete effectively within the industry.

2. The required research is too expensive for a single firm to undertake independently, or the research effort represents a leveraged investment.

3. The firm, as part of its business strategy, needs to establish a "window" on a particular scientific or technological area to keep abreast of a rapidly changing field of interest to the firm, to assist in making decisions to enter new fields, or to gain access to talent (professors or their students).

4. There is a need for independent validation of product or process requirements or performance.

Consequently, industrial firms tend to confine cooperative efforts to the following types of research activities:

1. Basic research is focused in areas that are of interest to the firm. When undertaken with competing firms, the basic research is not intended to produce particular products or processes, but to reveal underlying principles or to provide insight into areas that the individual firms can take into their own laboratories to use in the development of specific products or processes. The activities conducted in cooperation with other firms are at the pre-competitive stage. Patents or licenses are not commonly expected as an outcome.

2. Applied research is undertaken in noncompetitive areas generally related to process technology or instrumentation that will benefit the entire industry.

3. The applied research is related to technical data or knowledge needed to meet regulatory requirements affecting the industry as a whole.

4. The research deals with testing or establishing standards.

FORMS OF COOPERATIVE RESEARCH

The four broad categories of cooperative research activities are: (1) private consortia; (2) industry-university consortia; (3) industry-university partnerships; and (4) public user facilities.

Private Consortia

Traditionally, competing firms in the United States only occasionally participated in joint research efforts. Trade associations in many of the basic industries (e.g., chemical, food, paper, automotive, and textiles) were formed early in this century to serve as mechanisms for cooperative research efforts among association members. The association often sponsors research of generic interest to the industry, ensuring that the results are available to all members. Other industries (e.g., energy and telecommunications) have more recently formed research institutes with joint funding and shared results. Some institutes (such as the Chemical Industry Institute of Toxicology or the Council for Tobacco Research) were formed to conduct independent work related to the effects (environmental and health) of their products. The cooperative aspect of these activities centers on the shared funding of research by competing firms and the sharing of research results, generally of a nonproprietary nature or related to public concerns. By far, the largest amount of cooperative activity has occurred through trade associations.

During the 1980's, a variation on private industry research consortia emerged: the research corporation. The Microelectronics and Computer Technology Corporation (MCC), located at the University of Texas at Austin, is the primary example and model of the newer arrangement. MCC is a for-profit corporation jointly owned by 21 firms. Long-range research is conducted in four main programs to make significant advances in microelectronics and computer technology. The intent is to produce base technology that can be incorporated in a wide range of technologies and then used by the individual firms to develop new competitive products.

A distinctive aspect of MCC is that personnel from the member companies are assigned to conduct research at the MCC laboratory. Presently, about 17 percent of the research staff is supplied by member firms. The commitment is for 100 percent of an individual's time for a period of several years or for the length of the project. An additional 17 percent of the employees are liaisons. Each company sends one liaison for each of its selected programs. The liaisons spend about 75 percent of their time in the research program. The remaining 25 percent is allocated to liaison activities between MCC and the sponsoring firm. The purpose of the liaison activity is to promote the transfer of technology to the individual firms. The members consider this function to be of the utmost importance according to MCC's William Stotesbery (in Shirley A. Johnson, Jr. [ed.], Emerging National R&D and Management Trends, University Press of America, 1986). Because all of the research is in the pre-competitive stage (i.e., no marketable products are or can be produced), the transfer function must be provided by someone who is intimately familiar with the actual research and with the member's organization and technical needs.

Although MCC has elected to conduct most of its research inhouse (only five percent is expected to go to university researchers), other cooperative ventures have been formed that operate differently. For example, research for the Semiconductor Research Consortium (consisting of 35 firms) is contracted to universities. In this case, the member firms are more interested in longer-term basic research rather than shorter-term transferable base technology.

Increasingly, private consortia of the MCC and SRC types are becoming attractive to U.S. industrial firms. One of the primary influences was the enactment of the National Cooperative Research Act of 1984. The most significant provisions allow cooperative research activities up to and including experimental production and testing of models, prototypes, equipment, materials, and processes. Secondly, the incentive for third-party, anti-trust litigation is reduced by allowing only actual rather than treble damages in the event of a successful suit.

The Act was passed unanimously by Congress in response to the growing competitive pressure from the Japanese in microelectronics and computer technology. Many of the gains made by the Japanese have emerged through cooperative efforts. However, the Japanese and American models of cooperative research ventures are very different. In the United States there is a strongly held viewpoint that too much interaction among competing firms will inhibit competition. Consequently, although anti-trust laws have been significantly modified with respect to cooperative research activities, there are prohibitions against exchanging information about sales, profitability, prices, marketing, or distribution methods, since these are not required to perform the R&D activities. The Justice Department must review each consortium, including the members and objectives, in order for it to qualify as a cooperative venture. Since January 1, 1985, 54 industrial consortia have been formed with the consent of the Justice Department. A wide variety of industries are participating under the new provisions. Each consortium is different, with some conducting R&D solely among private sector firms and some participating with universities or Federal agencies.

Industry-University Consortia

Many types of industry-university relationships are often included in discussions of cooperative research, including the award of unrestricted grants for research; equipment donations; participation in conferences, workshops, and seminars; consulting arrangements; industry sabbaticals; industrial affiliate programs; and participation on advisory boards. Such relationships more properly fall within the broader category of industry-university interactions. In this discussion, the primary emphasis is on cooperative activities in which there is a direct connection between research conducted by university personnel and the technological needs of multiple industrial firms. Consequently, the above-mentioned activities are excluded, except as they are important in leading to cooperative activities or in transferring information or knowledge in the course of a more formal cooperative research arrangement.

Cooperative centers are a primary mechanism for conducting joint research efforts. The center concept provides a focus to university research, but is generally less restrictive than a contract or consulting agreement between the university or faculty member and an individual company. The center may be located in a separate facility or research may be conducted in several existing laboratories on campus, but the research has a coordinated purpose and direction. The general characteristics of the university centers are:

- Primarily, basic research focused in broad areas is conducted.
- The research is often confined to particular academic departments but is increasingly interdisciplinary.
- Broad research direction is provided by an advisory board consisting of academic and industrial members.
- The work is conducted by university faculty and graduate students.
- Contact with industrial representatives is usually limited to semi-annual or quarterly progress reports.
- Research results are published, although sometimes delayed, depending upon the particular agreements.
- Licenses are not common, and when they occur, universities prefer nonexclusive licenses.

There are two primary types of centers, which are categorized by funding source: (1) industrially funded centers; and (2) Federally funded centers.

Industrially Funded Centers

Some centers, such as the Textile Research Institute, that were formed to serve the needs of a specific industry and are supported by competing firms through a trade association are often located at universities or contract for research conducted by academic scientists and engineers. These have been previously discussed.

Another type of industrially funded center that is developing is characterized by participation of multiple firms from several different industries. Examples include The Materials Science Center at Lehigh University and the Center for Manufacturing Productivity at

Rensselaer Polytechnic Institute. These centers conduct basic research with potential applications in a large variety of industries. Most have evolved from long-standing relationships with individual researchers and industrial counterparts. A primary concern in these centers seems to be continuing and strengthening the ties between individual investigators at the university and industry (National Science Board, 1984).

Federally Funded Centers

The National Science Foundation (NSF) has established research centers for many years. The Lehigh Materials Science Center was formed in 1962 with a five-year development grant. During the early 1970s, a concerted Federal effort was initiated to strengthen industry and university relations, and the NSF designed and implemented a series of experimental programs in an attempt to discover appropriate institutional mechanisms. Two programs were initiated: the Experimental R&D Incentives Program and the University-Industry Cooperative Research (U-ICR) Centers Program. The Carter Administration continued the growing national emphasis on new institutional mechanisms to promote cooperative research and innovation by sponsoring the Industry-University Cooperative Research Projects and the Small Business Innovation Research Program. The Reagan administration has generally preferred the use of financial incentives (e.g., tax credits) to encourage cooperative research efforts.

The U-ICR Projects Program funds scientific and engineering research on a cost-sharing basis with industry. The projects are typically conducted by university faculty and scientists from a single firm working jointly for a limited time period. These projects are similar to traditional contractual and consulting agreements.

The U-ICR Centers Program differs significantly from the Projects Program. In these centers, several companies sponsor interdisciplinary work, usually over a period of several years. A more complex arrangement is emerging in which faculty members and students from several universities also participate with the multiple companies. The member firms pay an annual fee to participate, with the specific benefits and terms worked out in a cooperative agreement. Most of the centers originated through the initiative of universities or individual faculty members. Frequently, they are the result of close personal working relationships between faculty members and individual companies established through consulting or industrial affiliates programs. The early financial commitment and guidance provided by NSF is a major catalyst in establishing the centers. Industry indicates that access to graduates is a primary motivating factor for participation (National Science Board, <u>University-Industry Research Relationships</u>, 1982).

Industrial participants are generally pleased with the activities and results of the centers. Most of the participants are Fortune 500 or other large companies with substantial R&D budgets, only a small percentage of which is allocated to the NSF centers. Membership costs vary but average in the $30,000 to $50,000 per year range (see Denis Gray and Teresa Gidley, <u>Evaluation of the NSF University/Industry Cooperative Research Centers</u>, North Carolina State University, June 1986). Several firms participate in more than one center. The industrial firms are interested in focused basic research (and sometimes more applied work), and the small membership fee is considered a worthwhile investment. Funds for these programs generally compete with other R&D projects in the firm, and the investment must be justified annually. In most cases, tangible results in the form of technology that can be patented or licensed are not expected.

The Centers Program has a "market" orientation. NSF contributes to the support of the center for five years, after which it must become self-sufficient through industrial or other financial support. Several centers (e.g., the MIT Polymer Processing Program) are already self-supporting.

Engineering Research Centers is a new NSF program. The National Academy of Engineering provided advice on the organization and operation of the centers. In their 1984 report to NSF, the Academy enumerated the unique engineering center purposes, stressing cross-disciplinary research, which is required in an industrial setting, and their educational function. The purposes are:

1. To conduct cross-disciplinary research that would lead to the greater effectiveness and world competitiveness of U.S. industrial companies, and

2. To improve the education of engineers at all levels, and thereby increase the number of students who can contribute innovatively to U.S. industry and its productivity.

The Academy report recommended "specific working ties with industry" to provide "continual interaction" of faculty, students, and industrial engineers and scientists. The focus of the program is on the needs of practitioners. Secondly, the report stresses the need to synthesize engineering knowledge, including integrating different disciplines needed for problem-solving in the industrial setting.

Industry-University Partnerships

Partnerships between a single firm and a single institution are very different from other forms of cooperative research agreements and represent the exception rather than the rule. Examples that have received considerable publicity include those between Harvard and Monsanto, Exxon and MIT, Mallinckrodt and Washington University, DuPont and Harvard, and Hoechst and Massachusetts General Hospital. Partnerships are distinguished primarily by the level of industrial investment, ranging from $3.9 million to $50 million. The agreements are contracts for relatively long-term basic research, most often in the biotechnology area.

In these agreements, the university generally holds title to any resulting patents (the exception is Harvard-Monsanto). Exclusive licenses will be granted, except in the MIT-Exxon agreement. Exxon will receive a royalty free, nonexclusive license, but will share in royalty income from any third-party licensees. No publication restrictions are imposed on university researchers in any of these cases.

User Facilities

Prior to the latest technology transfer and cooperative research legislation, the ability of public institutions to share facilities with large firms was limited to circumstances in which a firm had need of "unique" facilities. A significant number of unique facilities in Federal laboratories and at universities have been used for this purpose. One example of an industry-university-government cooperative effort in this category is the Stanford University Synchrotron

Laboratory (SSRL), which is presently funded by DOE and NIH. There is a close and continuing relationship at SSRL among several major industrial firms, academic scientists, and students from several universities. In late 1984, there were 106 institutions using SSRL facilities, including universities (52), corporations (23), government laboratories (12), and foreign institutions (21). According to the laboratory's director, Arthur Bienenstock (in Shirley A. Johnson, Jr. [ed.], Emerging National R&D and Management Trends, University Press of America, 1986), of the 200 active proposals in progress, 50 projects are industry-university collaborations.

The laboratory uses Stanford's linear accelerator that produces high-energy electrons. The electrons are transported to a circular storage ring in which they circulate just below the speed of light. The circulating electrons produce radiation as their path is bent by the "bending magnets" of the storage ring, thus creating a radiation light beam that is "typically about 100,000 times as intense as that produced by an X-ray tube" (Bienenstock, 1986).

One of the first beam lines was built at SSRL by scientists from Xerox PARC. Xerox, Bell Laboratories, and IBM-San Jose contributed funding and the time of their scientists to develop instrumentation at the laboratory. All of these firms (and now others) continue to fund projects and to conduct research at the laboratory in conjunction with SSRL researchers, other industrial firms, academic researchers, and graduate students.

The development of the EXAFS technique, which allows examination of the atomic structure of complex materials, has been of great importance to several industries working at SSRL. The concept was developed at the University of Washington following the fundamental observations by a scientist at Boeing Laboratories. The instrumentation needed to demonstrate the concept's validity was developed in collaboration with scientists from Bell Laboratories, the University of Washington, and Stanford University. Since that time, the technique has been used extensively by academic and industrial scientists in studies of the properties of fossil fuels, semiconductors, metals, and glass; and the processes of oxidation and corrosion. Similar facilities are now at

Cornell University and Brookhaven National Laboratory. The DOE has announced plans to construct other major facilities in the near future.

Such facilities and instrumentation are extremely costly and often rare, thus providing excellent opportunities for Federal laboratories to establish and maintain cooperative research relations with a wide variety of collaborators.

INDUSTRIAL MOTIVES AND EXPECTED OUTCOMES

Technology-based innovation can make substantial contributions to the growth of emerging industries and to the revitalization or diversification of basic industries. Successful innovation requires creative people, adequate financial resources, available technology, a problem that requires a technical solution, and market acceptance of the firm's particular solution. A firm that adopts a technology-based innovation strategy must therefore give constant attention to methods of acquiring and managing the people, financial resources, and technology needed to develop and exploit market opportunities.

Participation in cooperative research efforts is one among many options a firm has for acquiring technological capabilities. Most often, cooperative research arrangements with public institutions are used as a method to gain access to people with particular capabilities, research results, or equipment the firm may need. In surveys of industrial participants, both the National Science Board (1982) and Gray and Gidley (1986) found that the strongest motive for entering into university cooperative agreements is to gain access to people: faculty working in areas of interest to the firm and students who may become future employees. Research results are second to recruiting as primary industry motivations. In private consortia, however, interest in research results and the cost-effectiveness of joint research efforts appear to be predominant motives. In either case, the decision to participate with other organizations or individuals outside the firm in a cooperative research arrangement depends on the contribution that the arrangement can make to the firm's overall competitive strategy.

Cooperative research efforts can serve short-term or long-term objectives. The motives for participation are influenced greatly by the firm's expectations of what the research will produce and how the results might be used within the firm. The selection of the appropriate type of agreement will depend on whether the firm is seeking to enhance its short-term or long-term capabilities as summarized in tables 1 and 2.

Short-Term Strategy

It takes about two to 10 years to bring a new product to market and possibly to adopt a new process, depending on the particular industry. This is the short term when considering a firm's innovation strategy. The most common options for obtaining technology for this purpose include:

- Purchase or license technology from another organization,
- Purchase or invest in a growing technology-based firm,
- Recruit experienced personnel from another firm,
- Conduct proprietary development work inhouse, or
- Establish a cooperative research arrangement under contract with another research organization.

Cooperative research efforts supporting a firm's short-term strategy can be conducted jointly with competing firms and university or Federal laboratories or on a one-on-one basis, with public laboratories cooperating with a single firm. The types of cooperative research arrangements that are most likely to be conducted jointly with competing firms are: (1) efforts to investigate processes of common interest to the industry; (2) efforts directed towards regulatory concerns; or (3) demonstration projects to establish feasibility. All three of these areas are basically noncompetitive, or more accurately "pre-competitive." Firms are often willing to work jointly on improving processes that have become standard in an industry because incremental changes will benefit all of the participants. Testing and process performance evaluation can be conducted by public institutions and is sponsored by industrial groups to provide independent validation to regulatory agencies. Firms may cooperate to demonstrate technical feasibility of new or innovative technology that is often developed by a university or Federal laboratory. In all these cases, cooperation is

Table 1. Summary of Industrial Cooperative Research Efforts Supporting a Firm's Short-Term Strategy

Objective	Type Research Usually Conducted	Size of Participating Firm	Type of Agreement	Industrial Use of Results
Process Technology	Applied/ Fundamental	Large	Consortia	Process improvement
Problem-Solving	1) Applied	Large or small	Consortia	Regulatory concerns, process improvements or standards and testing
	2) Applied	Large or small	Single firm contract	Contribution to process improvement or product development
Product Development	Applied	Small	Single firm contract	Commercializable technology, contribution to product development (e.g., demonstrate feasibility)

Source: Gulf South Research Institute, 1987.

Table 2. Summary of Industrial Cooperative Research Objectives Supporting a Firm's Long-Term Strategy

Objective	Type Research Usually Conducted	Size of Participating Firm	Type of Agreement	Industrial Use of Results
Educational	Fundamental/ Applied	Large	Consortia	Personnel recruitment (students)
Obtain "Window on Technology"	Fundamental	Large	Consortia	Access to frontier research conducted by faculty and graduate students to monitor results in a technological or scientific realm of interest to firm
Process Technology	Fundamental/ Applied	Large	Consortia	Contribute to new process development or process improvement
Product Development	Fundamental/ Applied	Large	Single firm contract	Patents

Source: Gulf South Research Institute, 1987.

attractive because there is no competitive advantage lost to an individual firm by participating and cost sharing reduces the level of investment required by any single firm.

Product development work is usually conducted as part of a short-term strategy, but is not performed in a cooperative endeavor with competing firms. However, it can be performed with laboratories and universities because they are not in competition with the firm. Typically, in development work, the fundamental concept for the product has been developed, technical feasibility established, and a prototype may have been demonstrated. The remaining work consists of turning the prototype model into something that can be manufactured for the commercial market. The original design may be modified several times to accommodate the firm's existing manufacturing capabilities, financial constraints, or market specifications. The applied research that is conducted at this stage is usually proprietary and is performed inhouse.

However, a firm may contract outside its own organization to acquire capabilities (people or research results) to solve specific problems related to the firm's internal R&D efforts. The closer a product is to market, the more the firm will consider its work as proprietary. The firm will want to protect information about the nature of work and the research results, possibly by using confidentiality agreements. It is at this stage of the innovation process that secrecy becomes an issue in dealing with individuals and institutions outside the firm. The difficulties of maintaining control of the technology outside of the firm limit the usefulness of cooperative research efforts at this stage unless the participants (i.e., universities or Federal laboratories) are fully aware of the firm's concerns and are willing to make the commitment to protect the results of proprietary work.

Exceptions may occur in situations where the research stage includes advanced basic research obtained from an outside organization or a laboratory has identified applications of its primary mission work. In these cases, the firm may need some assistance to expedite the development phase and may request further technical assistance from the outside laboratory. This work may be conducted under a cooperative research agreement or by a simple personnel exchange for a specified period. It may be necessary for the outside organization to work with the firm's manufacturing, marketing, and financial units as well as the R&D group. The cooperative agreement will generally be of relatively short duration, and the firm will have specific technical, marketing, and financial objectives with which the R&D effort must be compatible.

Many firms that do not have extensive inhouse research capabilities must also innovate in order to enter markets or to remain competitive. Laboratories offering technologies for license may be requested to provide technical assistance to these companies, particularly if they are new, small, or entering unfamiliar technical areas. The laboratory may conduct seminars to familiarize the firm's engineers with the technology, or the organizations may enter into a formal cooperative agreement to provide research services to the firm. The expectations for the firm are identical to the previous example: the work is proprietary and protection of the results is required; and specific technical, marketing, and financial objectives must be met in order to successfully commercialize the product.

Large or small firms may occasionally enter into a cooperative research agreement for the sole purpose of developing a product or a component of the product. For example, in the early 1970s DuPont established a one-year consulting agreement with a professor at Tufts University to develop a new toothbrush. The project was extended for four years and resulted in a patent and a successful transfer to DuPont. Johnson & Johnson subsequently purchased the patent from DuPont and successfully commercialized the product as the Reach Toothbrush.

As Harvey Jones' documentation illustrates (in <u>Commercialization of New Technologies: Transfer From Laboratory to Firm</u>, Massachusetts Institute of Technology, 1983), lengthy and complex interactions between the cooperating organizations are often required to successfully produce even a relatively simple innovative product. It also illustrates that DuPont's business strategy guided the initiation of the project and determined its final disposition. The R&D began as a result of management's decision to add an innovative product to its consumer division product line. Before the toothbrush reached the market, the firm made a strategic decision to divest the division. The transfer by DuPont to Johnson & Johnson was accomplished by selling the patent for a fixed percentage of sales during a specified period. The technology documentation and other studies were included in the sale. The transfer from DuPont to Johnson & Johnson took about nine months, in comparison to the four years required to complete the transfer from the university team to DuPont. A lengthy period was required because of the researchers' commitments to university responsibilities and several design modifications required to meet marketing and manufacturing criteria.

Small firms requesting product development work typically will not have the financial resources to devote to lengthy and complex arrangements. They will request and expect the laboratory to develop a product that is very close to a commercial design and that can be transferred with as little revision as possible. It is very important in these instances that the research organization understand not only what is requested, but what is possible within the firm's manufacturing capabilities (which may also be conducted outside the firm) and the features needed to suit the needs of the firm's customers.

Misunderstandings about laboratory and firm responsibilities and capabilities are most likely to occur in working with small firms seeking commercial products and will adversely affect the transfer effort. Richard Goldhor and Robert Lund present a good case study of a situation at MIT in which the cooperating parties undertook an association with completely different and incompatible purposes and expectations (University to Industry Transfer: A Case Study in Advanced Technology, Cambridge, Massachusetts Institute of Technology, 1981). In this case, five years were spent in developing a product for the handicap equipment market that could be used by universities for research purposes, but could not be used by the intended consumers (i.e., the commercial market). The research results produced little of value to the firm. This situation can be avoided by establishing clear objectives at the beginning of the project.

Successful transfers can be enhanced by researchers understanding that if a firm has established a relationship to improve its short-term competitive position, it will not be interested in research that has intrinsic value only to the researcher. Identifiable products that meet particular manufacturing and market specifications are required in order for the firm to successfully introduce the final product. This is particularly the case when a small company is involved because the company usually cannot withstand the financial effects of unsuccessful research efforts (from the firm's perspective) that occur as a result of fundamental misunderstandings about the expected outcome.

Long-Term Strategy

Participation in cooperative research efforts with other firms and research laboratories can be an effective component of a long-term technology acquisition strategy. Often, an individual firm is not interested in a particular technology, but more in obtaining access to developments occurring in a scientific or technological realm. Often the firm is less interested in the specific research results than in following the direction that the research is taking and in establishing relationships with the people conducting the work. In pursuing a long-term interest in the direction of the research, the firm generally seeks contacts with leading researchers in areas of interest to the firm. Consequently, most of the NSF university-industry cooperative research centers are staffed by senior level university researchers, who have established reputations in their fields.

Products are not generally expected to emerge from the cooperative activities. The research work tends to be multidisciplinary and exploratory, with some R&D effort. Patentable technology is typically not an expected outcome. In some industries where patents may be expected and play an important role (e.g., biotechnology), firms tend to enter into long-term cooperative agreements as single companies. In multiple-company industry consortia, if the research produces results of more immediate interest to the company, the firm will complete the R&D work inhouse.

The NSF has conducted extensive evaluations of university cooperative research centers funded by the agency and has found that there is very little interaction among the research personnel of the centers and the firms (Gray and Gidley, 1986). The university personnel select the research projects which are then reviewed by the industry participants. Progress on the research is communicated at quarterly or semi-annual meetings to the advisory board. The lack of interaction with research personnel between the university and the firm is not inconsistent with the firm's intention to gain access to people at the university. The firms are looking for academic researchers doing work at the forefront of their fields. They are interested in the research results to maintain a "window" on technology and in recruiting students trained by leading researchers. Both objectives can be met with minimal liaison with university researchers. However, some associations (e.g., Chemical Research Council) are now encouraging more direct interaction between university and industry researchers.

Conversations (GSRI, 1987) reveal that many of the industry center representatives pass research results along to their firm's management and R&D units, but because of the nature of fundamental research, it it often difficult to trace precisely how the results are used within the firm. However, responders to the NSF evaluation indicate that research projects have been initiated within the firm as a result of university research efforts.

The primary motives for entering into a university cooperative research arrangement with similar firms have been investigated by the NSF evaluators and by the National Science Board (NSB) in 1982. The motives as reported by each study are presented and ranked in importance in Table 3.

Although the survey categories are slightly different, it is clear from both that the cooperative research mechanism with universities serves the long-term objectives related to keeping at the forefront of expanding knowledge in a technical area and identifying promising students for employment. Neither objective is expected to produce products or commercializable technology. Technical goals, which received the lowest ranking in both surveys, include increasing the quality of industry research, establishing new research projects within

Table 3. Industrial Motives for Participation in University Cooperative Research Centers

Industry Motive	Rank in Importance, by Source National Science Foundation	 National Science Board
General Expansion of Knowledge in Technical Area, including Obtaining a "Window" on Technology	1	2-3
Personnel Recruitment and Training	2	1
Redirect University Research Toward Industry Problems	3	N/A*
Technical Goals	4	8
Access to Facilities	N/A	4
Enhance Image	N/A	5
Support Community Institution	N/A	6
Economical Resources	N/A	7

*Not Applicable.

Sources: Adapted from Denis Gray and Teresa Gidley, Evaluation of the NSF University/Industry Cooperative Research Centers, North Carolina State University, June 1986; and National Science Board, University-Industry Research Relationships, 1982.

the firm, patents, and commercial products. In the NSB survey, "technical goals" means problem-solving activities.

Obtaining access to a "window" on technology is not the same thing as acquiring a particular technology. The term refers to monitoring advanced work by outstanding scientists in a technological realm that influences a firm's long-term business prospects. Cooperative agreements related to the same realm of activity may be maintained with several individuals and institutions. For example, a large chemical company may have agreements at several (five or six) universities with six or eight individuals all doing work in different aspects of an area such as catalysis or polymer research. There may or may not be parallel efforts in the firm's laboratories. The research results may be very significant in the long term in providing new research directions. Small discoveries in several areas may ultimately be used in some way many years later in actual product development work. It is extremely difficult to trace the precise use of the previous research results because often they are not "used" so much as they provide the basis for new insights by the firm's researchers who bring together bits and pieces, or "threads," from the various disciplines and research areas to improve existing processes or product lines or to create new ones. The research results obtained by this method do not constitute a "technology," but may make a significant contribution to the firm's technical base.

Redirecting university research toward industrial problems appears to be a more immediate objective for participating firms. However, the NSF survey indicates that the intention of this type of support is related to educational rather than product development objectives and consequently is a long-term objective. The purpose is to provide research training that is closer to the industrial R&D setting (i.e., interdisciplinary research conducted by teams), rather than to produce products or to engage in problem-solving, except to the extent that the research is in a technical area of broad interest to the industry as a whole.

IMPLICATIONS FOR FEDERAL LABORATORIES

The interest in fostering increased interactions in the Nation's research community is an outcome of the present relationship between technological innovation and economic growth. Research and development has emerged as a significant contributing factor in achieving major public policy goals related to sustaining U.S. industrial performance, particularly in a highly competitive international economy. Because the boundaries between science and technology are becoming much less distinct and technological change is occurring rapidly in several important industrial areas, technology with commercial potential (or technical information that can make a long-term contribution to product development) exists and can be acquired from many different sources and by many methods. The Federal laboratories are an important potential source of technology and of personnel working in basic and applied research areas that may be of interest to large and small firms. Clearly the Federal laboratories can make a significant contribution to industrial growth, and cooperative research is one of the mechanisms that brings researchers and research findings together in a way that may contribute to a firm's innovation strategy or to an industrial consortium's interest in developing base technology or improved processes.

There has not been much interaction between industrial firms and most Federal laboratories, particularly with respect to cooperative research efforts. In their 1983 report, the White House Science Council concluded that the laboratories' highly competent researchers working on well-conceived programs and unique facilities are underutilized by industry. The Science Council recommended increased access to user facilities, greater opportunities for personnel exchange, and more collaborative projects as methods of strengthening research interactions that could enhance U.S. economic vitality.

New York University's Center for Science and Technology Policy prepared a report for NSF in 1984 entitled _Trends in Collective Industrial Research_. The report is primarily concerned with collective action sponsored through industrial associations rather than cooperative ventures such as MCC or cooperative agreements between a laboratory and an individual firm, such as the Monsanto arrangements with several universities. This report concluded that there is limited use of Federal and university laboratories by industrial associations. Six associations reported that they spent a total of about $395 million at Federal laboratories in 1982. Although a significant expenditure, the total represented only about five percent of the aggregate R&D expenditures by the associations. Most of the activity reported by 24 associations consisted of testing and measuring efforts, conducted primarily through the National Bureau of Standards' Industrial Research Associate Program. Applied research was the second highest category, followed by fundamental research, standards, prototype development, and pilot plants. Agencies reported very few direct cooperative research projects with firms or consortia. The types of cooperative activities included data analysis, testing and demonstration of laboratory-developed technology, contract work, and user facility arrangements.

Although the universities and Federal laboratories share important similarities, there are also important differences that should be taken into consideration in designing cooperative research arrangements with firms and industrial consortia. The differences may lend an advantage to firms working with universities in some situations and with Federal laboratories in others. The choice will depend on the firm's particular objectives. The laboratories can organize efforts to enlist industrial support in cooperative arrangements to enhance the probability of success by objectively assessing what capabilities the laboratory brings to the arrangement and what outcomes the laboratory expects as well as understanding industrial needs and expectations.

From a firm's perspective, if there is an interest in public relations and in the educational training of prospective employees, it probably will choose to work with a university. If a firm is interested in obtaining access to scientific research, it will tend to seek out researchers with the necessary capabilities, and it matters little if the person is associated with a university or a Federal laboratory. It should be noted that many cooperative research consortia have been formed on the basis of a good working relationship with an individual researcher. At first, a small contract may be awarded to the laboratory if the firm is not familiar with the staff. The purpose of the contract may be primarily to determine whether an acceptable, and usually informal, working relationship can be established between the organizations before committing resources to a large project.

The Federal laboratories offer more experience than universities in applied research, technology development, and management of large multidisciplinary research projects. Opportunities exist for Federal laboratories to participate in a variety of types of arrangements. Some laboratories are structuring cooperative research agreements with individual companies and with several firms in the same industry. This is a horizontal configuration. A particularly interesting arrangement is under discussion by a USDA laboratory with several firms in related, but noncompeting businesses within the agricultural industry. In this vertically integrated arrangement, the laboratory will develop extraction methods that will benefit several processing plants and the extracted materials will form the basis of product development efforts by several biotechnology companies.

Some laboratories are also participating with universities in forming cooperative research ventures. The industry-university-laboratory arrangement could offer industry the ability to combine the research management and technology development expertise of some of the Federal laboratories with the educational component that is supplied by the universities. Federal laboratories may also be able to structure multidisciplinary programs to provide students with hands-on training that is closer to the industrial setting than can be easily provided by universities.

Another situation could present cooperative research opportunities for Federal laboratories: potential commercial applications of primary mission work. In this case, if the laboratory evaluates its technology and identifies one or more possible applications that appear to be commercially viable, the laboratory may choose to seek a firm that will commercialize the technology. Since further development work will usually be needed, the interested firm may choose to enter into a cooperative agreement with the laboratory to establish the technology's feasibility as a commercial product. In some cases, before seeking a firm, the laboratory should consider making an internal investment to bring its technology to a point that will sufficiently interest a firm in commercialization efforts. As part of its technology management efforts, laboratory personnel will need to evaluate these situations carefully in order to determine whether the commercialization goal can best be met by further internal investment, seeking a cooperative agreement, licensing the technology, or using a combination of these alternatives.

The success in establishing more cooperative research arrangements with industry depends on the ability of the laboratories and their industrial counterparts to fully understand the capabilities and objectives of each of the participants. There is no formula for predicting what a particular arrangement might "look like." An individual firm's innovation strategy, the nature of its industry, and its internal R&D capabilities will greatly influence the type of cooperative arrangement that may be requested and the terms of the cooperative agreement. It is very likely that a laboratory will be called upon to participate in several types of arrangements. Laboratories may be expected to perform research with stated objectives and performance schedules. Since these endeavors are fairly new, they should be viewed as experimental and it is important that laboratory personnel have the flexibility to adapt to the needs of a particular situation.

Issue Paper V

COOPERATIVE RESEARCH:
THE UNIVERSITY EXPERIENCE

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Gulf South Research Institute

Technology transfer efforts have focused a considerable amount of attention on the role of the universities in enhancing technological innovation and the U.S. competitive position in a global economy. The modern university in the United States performs three basic functions: (1) teaching, (2) research, and (3) service. At first glance, it seems odd that the role of the university in technological innovation would attract such a great deal of national attention. Most technological R&D and innovation takes place in the private sector. The universities are the major performers of scientific research in the United States and the realms of science and technology, although related, are distinct. However, although the universities do not directly participate in the technological innovation process (except in a very few cases), the universities' teaching and research functions are indirectly, but importantly, related to the innovation process.

The role of university scientific research in the development of technology is neither clear nor well-understood because it most often functions in an indirect and supporting capacity. Science per se does not lead to technology. Scientific discoveries must be converted or, more properly, used to inform technological achievements. The realms are distinct and operate within structures with differing purposes, objectives, and expected outcomes, although developments in either may provide contributions to the other.

In the United States, basic research is conducted primarily by university faculty, and technological R&D is conducted by industry. The Federal laboratories perform mission-oriented research in support of the objectives of their respective agencies. The agencies fund a large percentage of the Nation's basic research in support of their mission responsibilities. Most of this work is conducted by Federal laboratory or university personnel. The Federal laboratories (along with industrial firms) perform most of the Federally-funded applied research and development work.

As the United States has experienced intense economic competitive pressures, particularly from the Japanese and Europeans, increased interest has developed in strengthening the research relations between public sector researchers in universities and Federal laboratories and private sector researchers in industrial firms. Cooperative research arrangements between universities, Federal laboratories, industrial firms, and small innovative companies have been encouraged and authorized by Congress as a technology transfer mechanism intended to accelerate the innovation process in the United States, thereby contributing to industrial growth.

Cooperative research brings together private sector firms and public sector researchers to conduct research of mutual interest and benefit to the participants. Cooperative research ventures have been actively encouraged at major research universities. The National Science Foundation (NSF) has provided "seed money" to help establish cooperative research centers since the 1970s, and several states have contributed significant resources to university research centers with industrial support in an effort to assist local growth companies and to attract other firms to the area.

Universities have initiated most of the university-industry cooperative research ventures (National Science Board, University-Industry Research Relationships, 1982). Industrial firms have a long history of providing a modest level of support for university research. Industrial support is not expected to increase significantly and is eclipsed by Federal funding for university research. Participation in cooperative research ventures offers university faculty an additional source of Federal funding.

Industrial participation is required as a precondition of Federal funding for NSF centers and also adds to the research support. Most of Federally-funded cooperative research centers are expected to rely completely on industrial funding within five years of initiation. Industries participate in university-based cooperative research ventures primarily to obtain access to promising graduate students performing research in areas of interest to industry. Particular technologies are not an expected outcome; however, firms are interested in information concerning the direction the basic research is leading.

The prospect of closer research relations with the private sector has created problems as well as opportunities for many university administrators and faculty members. Although there are differences between universities and Federal laboratories, they are both publicly-funded institutions, and the administrative and research personnel share similar values. Cooperative research ventures is a major technology transfer mechanism recently authorized by Congress. The Federal laboratories are given considerable latitude and responsibilities in establishing and operating cooperative research ventures, and some of the issues that universities have dealt with in working out this type of interaction with industry will also be of interest to Federal laboratory management and personnel.

However, before proceeding, it will be useful to provide background information about the institutional settings in the public and private sectors in which the major types of research are conducted as a foundation for examining the issues surrounding cooperative research ventures.

INSTITUTIONAL SETTINGS FOR SCIENTIFIC AND TECHNOLOGICAL R&D

Since World War II, the funding for scientific research has increased dramatically. The Federal government has consistently increased funding for basic research, although the rate of increase varies considerably. University faculty members and Federal laboratories have been the primary beneficiaries of this funding. The rationale for government action is that it is appropriate for the public sector to fund basic research at universities because: (1) basic research expands knowledge; (2) basic research is integral to the education process, particularly at the graduate level; (3) graduate research programs are the training ground for the Nation's next generation of scientists and engineers; and (4) basic research contributes to technological development and innovation. With respect to the last point, the justification for Federal action is that it is too expensive for industry to perform entirely, because the outcomes are uncertain and transforming scientific discoveries into technological outcomes is a lengthy and expensive process, when it occurs at all. Consequently, firms must necessarily invest financial resources in applied research areas where the outcomes are more predictable. In each instance, basic research serves a public good by: (1) expanding the realm of scientific inquiry and knowledge that is available to all; (2) educating students; and (3) indirectly contributing to technological progress.

The education function and the contribution that scientific discovery makes to technology development also promotes the economic and social well-being of the entire citizenry through industrial expansion and the creation of better technology to solve problems (e.g., environmental and health). University-trained researchers will find employment in the university system, industry, or the government. Thus, the type of education that students receive and the type of research that is conducted in the educational setting is of critical importance to a variety of organizations in the public and private sectors.

Science is expected to expand knowledge and is conducted for the sake of knowing. It is not usually important to the researcher that the science is <u>used</u> by anyone because the purpose of the work is simply to understand the phenomenon. It is conducted in an atmosphere of the open exchange of ideas and information which are available to the benefit of all.

Technological R&D conducted by industry is expected to produce processes and products that can enhance the competitive position of the firm investing in R&D efforts. Firms must engage in innovation not only to grow, but to survive in an increasingly competitive environment. Success in R&D efforts (almost all of which is applied) is measured by how much the product or process that embodies a new technology is <u>used</u> by the firm's customers as measured in profits to the company. In other words, an innovation may be a technical triumph, but it is harmful to the firm's competitive position unless it is adopted by the firm's customers. Achieving a sufficient return on the investment is the only rationale a company can have for investing in R&D efforts, and profits are the only measure of evaluating its R&D

programs. Therefore, protecting the research findings and any resulting technology from use by other competing firms is often of critical importance. Firms are actually protecting their investment in the research effort and marketing costs associated with integrating innovative processes into the firm's manufacturing operations or with bringing new products to the market. Without this protection, the firm would be unable to compete effectively with other firms and could not sustain growth.

Government laboratories conduct scientific work and technological R&D. Because each of the laboratories supports the mission of its agency, even the science that is conducted in the laboratories has a purpose and therefore is not funded simply for the sake of knowing. Many of the laboratories engage in applied R&D and in projects to demonstrate technical feasibility, especially when the technology is highly experimental. The work conducted by Federal laboratories, like the universities, serves a public good by producing information or technology for the government's use or by demonstrating the feasibility of concepts or technology that is too costly for an individual firm to undertake but may be of interest to an entire industry or to the general public. Many of DOE's research projects in innovative energy technologies serve as an example of the latter case.

In most cases, the work conducted by the laboratories, particularly in the scientific area, is openly published. Because government-funded technological R&D is often intended to benefit the public by benefitting industries (rather than individual firms), these research results are also widely distributed. Like firms, however, many Federal laboratories are familiar with maintaining secrecy. The purpose of restricting access to research results is not to protect competitive position, but to protect national security, thus still serving a public rather than private purpose.

COOPERATIVE RESEARCH ISSUES

Universities, industrial firms, and Federal laboratories are governed according to the objectives each type of organization seeks to accomplish. The interest that each type of organization will have in participating in cooperative research ventures and its approach to establishing an agreement are greatly influenced by its purpose, objectives, organizational structure, and the way research is managed within the organization. The differences in each of these institutional characteristics underlie to some extent all of the issues that have emerged related to establishing and operating cooperative ventures. With technology transfer established by Federal policy as a public good, the central question for universities was expressed in 1982 at a meeting at Pajaro Dunes of five university and 11 corporate presidents: How can the universities preserve open communication and independence in the direction of basic research while also meeting obligations to industry? (See William J. Broad, "Pajaro Dunes: The Search for Concensus," Science 216 [April 9, 1982]:155).

The issues for universities and industry vary somewhat, but as these experimental cooperative endeavors have been established, both parties have exhibited a willingness to accommodate the other's underlying value system and to reduce institutional barriers that limit the initiation and conduct of cooperative activities. Most of the issues that have been raised have not materialized in practice. Others have been resolved through traditional university mechanisms, mutual agreement, or legislative action. A few are still under examination and remain unresolved. The primary issues for universities relate to: (1) the exchange of ideas and information; (2) research independence; and (3) conflict of interest. Issues of major concern to industry include: (1) antitrust considerations;
(2) exclusivity vs. nonexclusivity; and (3) the education and training of scientists and engineers.

Exchange of Ideas and Information

All three of the university's basic functions (i.e., teaching, research, and service) are based on the free and open exchange of ideas. The university's value system and reward structure support the pursuit of science and the dissemination of research results. Science is built on the work of others, making access to research results critical to the continuation of advances. Research results are shared with graduate students and other scientists on a routine basis through teaching, publication, presentations at conferences, and conversations with colleagues. Additionally, university tenure and professional recognition in a scientific field are directly related to the ability of the professor to publish and to communicate research findings.

Industry must necessarily protect its trade secrets and technological developments in order to maintain its competitive position. Information about a company's products or new processes is nearly always considered proprietary information and must be held confidential. Also, if the firm is considering patenting a technology, premature disclosure can prevent the firm from securing protection in the United States and abroad.

Many members of the academic community have expressed concern that industry's dependence on proprietary information and the need to protect its trade secrets and research findings will adversely affect one of the university's most valued traditions and could inhibit scientific advances by restricting the dissemination of research results. The problem is particularly acute in fields where the boundary between scientific research findings and possibilities for commercial applications may be almost indistinct. According to testimony presented before a subcommittee of the House Committee on Science and Technology (1981), the problem of proprietary restraints on the free exchange of data was appearing at biomedical research meetings and already affecting the "informal roots of communication that characterize most vigorous fields of basic biological research." (See U.S. Congress, House Committee on Science and Technology, "Commercialization of Academic Biomedical Research Hearings, 97th Congress, 1st Sess., 1981, p. 14).

Resolution of Issues

There is no doubt that the health and vitality of science in all fields is dependent on the open exchange of ideas and information. The unrestricted dissemination of information and data supports a public purpose to advance science. In the realm of technology, advances are also built on the work of others, and in this sense the two realms of science and technology are similar. The difference is that with respect to patented technologies, the incentive provided by the government to individuals and firms to disclose inventions or concepts is that they are protected from infringement of the use of their ideas and technologies by others for a specified length of time. Protection through proprietary methods of patents or trade secrets also serves a public purpose. By increasing competition and creating an impetus for technological advance, competing firms must modify the patented portion of a commercially successful technology enough to avoid infringement penalties.

In existing cooperative research ventures, the objectives of the participants and the type of work that is being performed determine the type of cooperative arrangement that is most appropriate and the terms by which information and data are treated. In a cooperative venture like the Microelectronics Computer Technology Corporation (MCC), basic research results are shared. Researchers from competing firms are conducting basic research needed by all the participants to make technical advances, but ideas for applications are considered proprietary. Each firm conducts its own in-house research effort for applications.

Research findings are also shared in cooperative efforts conducted at universities under the sponsorship of industrial associations. Often this work, whether it is basic or applied, involves process improvements of interest to the entire industry or regulatory or public concerns about an industry's products or processes. Research results can be shared in both cases because the nature of the work is non-proprietary and will not limit an individual firm's ability to compete effectively with other firms.

In most of the NSF cooperative research centers, basic research is conducted in a general, but focused, area of interest to the participating competing firms. Many firms are interested in recruiting talented graduate students doing advanced work and in obtaining advance information on the direction the research is leading a particular field. Proprietary work is not conducted with competing firms and patents are not an expected outcome. Publications are not restricted, although industrial participants usually expect to review publications prior to release. Because publication per se has not been restricted, the issue has focused on the length of time required for review. The release of published results depends on the terms of the initial agreement and the outcome of the research. In general, industrial members monitor the results of the work at quarterly or semi-annual meetings and thereby gain information about the progress of the work before it is published. In a 1982 National Science Board survey (University-Industry Research Relationships), the prepublication review period varied from no delay to one year, with one to six months reported most frequently.

Restricting research publications has tended to surface during the establishment of the research centers, but has not been an issue in the operational phase (see Denis Gray and Teresa Gidley, Evaluation of the NSF University/Industry Cooperative Research Centers, North Carolina State University, 1986). Although patents are not an expected outcome, the research agreement must take into consideration the rights and disposition of technology that may result from the research and the related publication issue. It is important to remember that the research agreement is a legal document and consequently potential situations and events are considered in drafting the agreement to avoid confusion and misunderstandings. It is also important to protect the tax exempt status of the university as a nonprofit institution. In most cases, the university holds the patent rights, granting nonexclusive licenses to participants in the center and other firms. The ability to publish results within a reasonable time period allows the university to show income from any royalties as unrelated business income, thus taking advantage of IRS exclusion allowed to nonprofit organizations (see Bernard D. Reams, Jr., University-Industry Research Partnerships, Westport, Connecticut: Quorum Books, 1986, pp. 84-89). The primary objectives of all the participants are met. The industrial firms obtain information prior to publication and access to leading researchers and their graduate students. University researchers are able to publish their findings, and in the event that patents and licenses are an outcome, the university benefits financially.

In some cases, an individual firm may be interested in university research that offers commercial possibilities or university researchers may have particular expertise needed by the firm to solve a particular problem. The work required may be basic or applied research, depending on the nature of the problem. The firm will have specific business objectives in establishing a relationship with university faculty. Under these circumstances, the firm will not be interested in participating in a cooperative research arrangement with other competing firms. It will prefer to enter into an agreement that is very similar to a consulting arrangement. For short-term research, a consulting agreement may be the most appropriate mechanism for interaction. Proprietary information can be shared and confidentiality maintained. For basic research that offers long-term commercial potential, a cooperative agreement may be structured between the university and the firm. The university generally holds any patents resulting from the research and typically grants exclusive licenses to the sponsoring firm. Many of the biotechnology cooperative ventures between universities and individual firms are engaged in basic research that may have near-term commercial benefit. Nevertheless, publication of research findings has not been restricted. From a firm's perspective, it is not necessary to restrict basic research findings because this information alone is insufficient to create technology. The proprietary applications work that leads to product development will be conducted in-house by the firm.

Research Independence

The second important issue that has been raised concerns the effect of industrial funding on the independence of academic research. There are two related elements within this broad category: (1) the effects on the objectivity and credibility of university research; and (2) intellectual freedom to pursue scientific inquiry.

The public's perception of the academic researcher engaged in the disinterested pursuit of knowledge for its own sake contributes to the perceived objectivity and credibility of the university, its researchers, and their research findings. It is often the case that the credibility of research findings is established in the public's mind by who is conducting the research. There are many areas in which there is a significant need for objective research conducted by impartial scientists and engineers to assist Federal and state agencies in regulatory situations and in providing thoughtful but disinterested observations and recommendations in public policy matters. University faculty are often called upon to provide these services. Many faculty members are concerned that their reputation for unbiased reporting of research findings will be damaged by accepting industrial funding.

The second element, the intellectual freedom to pursue scientific inquiry of interest to the individual researcher, is part of the larger issue of academic freedom. The tradition of intellectual freedom, tracing its roots to the Greeks and the European universities of the Rennaissance, is one of the primary values held by academic researchers. Scientific research requires the disinterested pursuit of new knowledge by the researcher. The corollary is that university researchers should be allowed to pursue scientific inquiry without interference and without reference to specific outcomes, scientific or commercial.

Resolution of Issues

Researchers are firmly convinced that the advancement of science requires the ability of the scientist to choose both the research topic and the method of inquiry. Nevertheless, research requires funding and the reconciliation of the interests of the funding source and the need for intellectual freedom has never been fully accomplished. Consequently, faculty prefer unrestricted research grants or contributions.

The assertion that university researchers are engaged in the disinterested pursuit of science at universities is questionable. In the 1950s, the massive Federal support for university research reduced the importance of limited industrial support and provided long-term commitments to research programs. However, the majority of Federal research support is provided and justified as support to the mission responsibilities of Federal agencies, thereby focusing the Nation's scientific research efforts in areas of interest to the agencies and in which funding is available.

In discussing the relationship of public funding to the objectives of scientific research, Derek Bok observed that the public funds science as a means to technological ends (see Beyond the Ivory Tower: Social Responsibility of the Modern University, Cambridge, Massachusetts: Harvard University Press, 1982, pp. 151-152):

> It is often said that the highest goal of academic science is to pursue knowledge for its own sake and not for the purpose of achieving specific practical results. This ideal is constantly at risk in a world where scientific research depends on heavy support from public funds, for the public is chiefly interested in discovery not as an end in itself, but as a means to new products, new cures for disease, or new solutions to pressing social problems.

The intellectual freedom problem is accommodated primarily by allowing university researchers to submit proposals for grants (rather than contracts) in areas of broad interest to the agencies, with the researcher generally selecting the research topic and methodology. Much of the funding is allocated to exploratory research in areas that do not have apparent applications. The quality of the research is protected by peer review of the proposal and the findings published in refereed journals. In addition, the agencies usually enter into contractual arrangements for applied research to resolve particular problems or to address specific agency concerns. University faculty are free to submit proposals in these areas and frequently do so.

Public funding for science presents problems of research independence for university faculty; however, issues are magnified when private funding is involved because the public-good argument carried with public funding becomes less compelling. There is a widely-held perception on university campuses that industry is only interested in short-term applied research with definite product or process applications that will benefit the company financially. Many university faculty and administrators contend that the a researcher's independence in selecting research topics and methods of inquiry is critical to the contribution that science makes to the public good. It is felt that this independence may be compromised by industrial control (as the funding source) over the topics that are investigated and possibly the method of inquiry. Additionally, industrial funding that exhibits a short-term product orientation may threaten scientific inquiry by focusing researcher's interests on applied research problems rather than advancing the realm of scientific discovery. Research conducted for the public good may be redirected to research conducted for private benefit.

A comment made by Howard Goodman in an interview with Science (1982) about the agreement between Hoechst and Massachusetts General Hospital illustrates the sensitivity of the subject and reflects a widespread scientific attitude about industrial research funding. Dr. Goodman stated unequivocably that (see B. J. Culliton, "The Hoechst Department of Massachusetts General," Science 216 [June 11, 1982]:1202):

> Hoechst has no influence on the direction of research ... Contractual legalese aside, as far as I'm concerned, this ($70 million) is a grant. This department is not an industrial extension.

In Beyond the Ivory Tower, Bok supported faculty participation in industry-sponsored collaborative research ventures. He noted that these ventures allow university researchers to investigate intellectually stimulating scientific problems that may result eventually in practical applications that will benefit society. They also offer graduate students an opportunity to become more familiar with industrial research needs and practices.

The academic perception that industry is only interested in short-term applied research problems with definite product or process applications has proved unfounded. Most of the work is basic research in areas of interest to faculty and industry. The NSF evaluation of their sponsored university-industry cooperative research centers indicates that senior faculty with established reputations in their scientific fields conduct the research. Tangible results are not expected by the industrial sponsors. Since the universities have initiated most of these arrangements, the responsibility of proposing the basic area of research has been within the control of the faculty. Once the general research area has been agreed upon and industrial participants have been recruited, the choice of research topics is also left to the discretion of the principal investigators. Proposals for research projects may be included in the initial proposal to potential industrial sponsors and typically represent a "portfolio" of projects, some (but not all) of which will be of interest to each of the participating firms (see W. A. Hetzner and J. D. Eveland in Jerry Dermer [ed.], Competiveness Through Technology, Lexington, Massachusetts; D. C. Heath & Co, 1986, pp. 177-191). Progress is monitored by an advisory board consisting of industrial representatives (usually a senior research manager) and university scientists. The research agenda can be modified with the consent of the advisory board.

It should be recalled that industry's primary purpose for entering into cooperative research centers is to gain access to promising graduate students doing work in areas of interest to the firm. Another important objective is to obtain a "window on technology," meaning following the direction of leading basic research which may influence the firm's internal R&D in the future. Neither objective is incompatible with academic research objectives.

Some cooperative research ventures are engaged in applied research related to regulatory issues and to process improvements. In both cases, the research is of interest to the industry as a whole but is too expensive to be supported by individual firms. The research topics are mutually agreed upon based on research objectives and the interest and area of expertise of the university researchers.

In general, it is unlikely that industrial funding would result in the redirection of the university's orientation from basic to applied research for three reasons. First, industry has an interest in supporting the vitality of university research as the major source of basic research that industry is unable to support independently. Secondly, the level of funding contributed by industry to all university sponsored research represents only about three percent of industry's research budget (NSF, 1985 National Science Indicators) and is miniscule in comparison to Federal funding of academic research. Industrial research managers speculate that it is unlikely that industry funding (in the aggregate) will ever approach even 10 percent of academic research funding. A third reason is that maintaining competitive market advantage limits cooperative research with competing firms to basic research, with the applied work leading to marketable products and proprietary processes conducted by the individual firms.

Conflict of Interest and Conflict of Commitment

Cooperative research efforts raise potential conflict of interest and conflict of commitment issues for universities. Conflicts of interest are legal questions concerning university personnel involvement in financial transactions. Conflicts relating to the performance of mission responsibilities are often referred to as conflict of commitment and are essentially R&D personnel management questions. These issues are grounded in the acknowledgement that the prospect of financial reward presents temptations from which researchers, like others, are not immune.

Conflict of Interest

Payments to individuals within the university by external sources has been an issue at university campuses since faculty members were first allowed to establish consulting relationships. The additional income supplements faculty salaries and provides experience with current industrial or business problems that can often be used effectively in teaching. Nearly all universities allow faculty members to engage in private consulting activities and many of the best technical universities actively encourage it. With the increasing emphasis on commercializing technology, licensing arrangements with royalty provisions raise the issue of the appropriate boundaries delineating legal and acceptable practices. For universities, the National Association of College and University Business Officers' professional code of ethics, university policies, and state ethics codes provide the standards and guidelines defining legal and acceptable practices. The comparable provisions for Federal employees are contained in the U.S. Code, Title V. It is important in structuring cooperative research agreements to adhere to these provisions. Both the universities and industry have been especially careful not only to avoid conflicts of interest but also the appearance of potential conflicts.

The private sector, especially large companies, does not usually allow researchers to share royalties or other income that results from their work. The private sector researcher's job description is based on performing research that will benefit the company. However, university faculty perform research in conjunction with teaching and other university responsibilities (e.g., committees). The university faculty member has many demands placed on his time in carrying out the basic mission functions of the university and the reward structure is based on the performance of these functions reflected primarily in published research papers.

In an effort to increase the benefits of Federally-funded research, Congress allowed nonprofit institutions (primarily universities) to retain title to technologies developed by university researchers. The university was then in a position to transfer the technology to the private sector for commercialization. As an incentive to faculty members to develop technologies and to participate in technology transfer efforts leading to commercialization of university technologies, researchers have been allowed by many universities to accept royalty payments. Many universities have established guidelines for royalty sharing with faculty members. These guidelines can be used in negotiating licensing agreements or in structuring cooperative research agreements. Congress has provided a similar financial incentive to Federal researchers. The Federal Technology Transfer Act of 1986 requires agencies to share royalty income with individual researchers developing technology that is subsequently transferred for commercialization.

Conflict of Commitment

The conflict of commitment issue is not concerned primarily with but is related to the ability of public employees to benefit personally from technology transfer efforts. As mentioned previously, royalty payments are offered as an incentive to encourage the participation in transfer efforts by researchers working in publicly-funded institutions. The financial incentive is prompted by an underlying understanding that the active participation of the researchers working with a particular technology is often critical to a successful transfer effort. However, career advancement is based on the performance of mission responsibilities, often measured by publications. In technology transfer activities, publications are an important, but a preliminary, mechanism that generally only initiate contacts for establishing other methods of collaboration and transfer. Additionally, premature publication may jeopardize transfer initiatives.

Some university administrators and faculty feel that greater involvement by university researchers in cooperative research ventures or other transfer mechanisms and the prospect of personal financial benefit outside the traditional university reward system may divert the researcher's time and possibly interest from serving the institution's mission. An example of the types of situations that may occur is provided by the National Science Board (in University-Industry Research Relationships, 1982, p. 113):

> A principal investigator has a new graduate student who is particularly good in a field he knows will be of interest to a company with which the professor has a consulting relationship. The professor obtains fellowship support for this student from the company. The professor and the company devise a program for the student's thesis research, following which the company gives research support to the professor for this program. Other research conducted by the professor in a related field is supported by the federal government. The professor maintains his consulting contract with the company and it is through this arrangement that company proprietary information is handled. Yet some of this information is relevant to the student's thesis.

In this example, several issues are raised. The professor may have a conflict of commitment because his first responsibility is to serve the university's mission of education and research. The education of the graduate student may be hampered by the professor's inability to share proprietary information with this student. A case could be made that no other graduate student has access to the proprietary information and therefore the student's education is not adversely affected by lack of the information. Nevertheless, graduate students are attracted to schools by the qualifications and expertise of faculty. If the faculty members are not able to share information gained through consulting (thus also raising the free exchange of information issue), the institutional rationale for allowing faculty members to consult as a method of improving instructional capabilities is considerably diminished.

Resolution of Issues

Through dealing with faculty consulting activities, most universities have established procedures for evaluating the effect of extramural relationships on the ability of the faculty member to adequately perform his primary responsibilities of teaching and research. The burden is usually placed on the individual researcher, and universities rely on voluntary disclosure by the faculty member as the primary method of determining the propriety of actions. The monitoring mechanisms (e.g., ad hoc review committees, policy committees, and policy guidelines) established at most research universities have provided a solution to the problem of balancing mission responsibilities with extramural activities.

In most situations, the universities have been able to work out suitable procedures that accommodate the philosophy of the individual university and faculty members and allow interactions with the private sector through consulting arrangements. However, the conflict of interest and conflict of commitment issues have both presented particularly troublesome problems for universities and faculty members in situations where the university or a faculty member holds an equity position in a company and is doing related research in the university. Faculty equity positions in companies received a great deal of public attention as professors in the biological sciences began to hold equity positions in biotechnology companies formed to commercialize the results of their research efforts. The work was often performed at university laboratories with university equipment (often Federally-funded).

In this situation, the faculty member has clearly used publicly-funded facilities and equipment for personal gain. If the university does not have a policy governing the ownership of technologies developed using university facilities and equipment and the faculty member resigns from the university to form a company, the university has also lost a faculty member and probably a good researcher. Additional problems occur when the faculty member remains on staff at the university while developing a company or serving as a consultant to a firm in which he holds an equity position. In this situation, the potential for the faculty member to risk a conflict of commitment is increased. The faculty member may be tempted by financial rewards to continue to use university facilities and equipment to conduct research of importance to the company. The faculty member's time spent on teaching and disinterested research may be diverted to the research needs of the company. Furthermore, the professor may direct the selection of graduate research theses to areas that would benefit his personal private sector interests.

Cooperative research agreements are established with the university and a proportion of a researcher's time is allocated to this venture. Furthermore, most of the cooperative research centers conduct research that is compatible with participating faculty member's teaching and research responsibilities. With a clear initial understanding by the industrial and university participants about the scope of research activities in terms of cost, personnel, and time, the conflict of commitment issue can be clarified and kept in the proper balance and perspective.

While most universities have accommodated faculty consulting arrangements by allowing a portion of the employee's time to be spent in activities outside the scope of primary mission responsibilities, a line has been drawn with respect to faculty equity positions. Many of the major research universities do not accept equity positions in companies and some do not allow faculty members to hold equity positions in companies while remaining on staff, thus forcing the issue of commitment. In others, faculty may hold an equity position, but may not receive funding from that company or other equity partners in the company. For example, at the University of California at Davis, Allied Chemical Corporation provided a $2.5 million grant to the university to use recombinant DNA techniques to confer nitrogen fixation capabilities on plants. A plant geneticist at the university was not allowed to receive funding from the grant because Allied Corporation had purchased a 20 percent interest in the professor's biotechnology firm (see C. W. Gehrke and R. W. Zumwalt, "University-Industry Coopertive Research: Expectations, Rewards, and Problems," in Dennis J. Runser [ed.], Industrial-Academic Interfacing, ACS Symposium Series 244, 1984).

Implications for Federal Laboratories

Most of the problems that universities have experienced do not threaten the Federal laboratories. Of course, personnel standards must be in compliance with Federal law and regulations. The conflict of commitment has been obviated by the Federal Technology Transfer Act of 1986 and the 1987 Executive Order which clearly make technology transfer efforts (including cooperative research activities) a new mission for the laboratories and their personnel. The legislation authorizes royalty payments to the laboratories and personnel and defines the acceptable uses by the laboratories for these funds. Royalty payments to individuals are generally modest and are offered as an incentive to interest laboratory personnel in actively participating in technology transfer activities.

The provisions of the technology transfer legislation indicate that laboratories will be responsible for managing their own technologies for the purpose of achieving commercializable technology. Questions of the proper allocation of research personnel with respect to agency mission responsibilities and technology transfer mission activities will become part of the laboratory management decision-making activities. These decisions should be based on the overall needs of the laboratory and its respective agency with respect to dual mission responsibilites and interest of the research staff in participating in cooperative research ventures and other forms of technology transfer.

The need for difficult decisions with respect to commitments of personnel time can be reduced best by designing R&D projects that meet both government and private sector objectives where possible. In this case, cooperative research ventures serve as a vehicle for accomplishing primary mission and technology transfer objectives.

The Federal laboratories may also expect to deal with conflict of interest and commitment issues when the laboratory or their personnel hold equity positions in private firms. The problems that Martin-Marietta has as a contractor operating a laboratory serve as an example. As part of a very innovative technology transfer program for Oak Ridge National Laboratory, proposed by Martin-Marietta to DOE, Martin-Marietta financed the construction of the Tennessee Innovation Center, located in Oak Ridge. Some of the firms located in the Innovation Center were founded by laboratory employees who have formed companies, some of which are based on technology that was initially developed at the laboratory. Martin-Marietta, as the owner of the Innovation Center, operates the facility like many similar centers established at universities. In return for reduced rent and the provision of office services, the owner of the center assumes a negotiated equity position in each of the firms located in the center. It is envisioned that any equity income will be used to finance the operations of the center and to provide additional income to the owner. The DOE has expressed concern about the propriety of Martin-Marietta's equity relationship with these companies stating that it may be a conflict of interest for Martin-Marietta to participate on an equity basis in companies that are based on technology licensed from the laboratory by former employees of the laboratory. The General Accounting Office initiated a lengthy investigation of the situation and according to laboratory personnel found no improprieties. According to David Fitzgerald, director of the center, the founders of these startup firms are penalized for former employment at the laboratory because of the conflict of interest issue between Martin-Marietta and DOE. For example, proposals submitted by the startup firms to Federal agencies are "flagged" because the conflict question (for Martin-Marietta) has not been resolved.

The resolution of this situation will be important for all the laboratories and their employees. The 1984 and 1986 technology transfer legislation specifically gives Federal employees (present and former) the right to obtain the rights to Federally-funded technology and to commercialize that technology if the laboratory or agency does not choose to exploit its commercial potential by transfer to the private sector. In some cases, the best (and occasionally, the only) way to commercialize the technology will be to form a company. The penalties imposed on the new firms because of their former relationship with Oak Ridge would appear to defeat the purpose of allowing employees to commercialize technology. However, Martin-Marietta's equity position in these firms appears to present the primary obstacle.

Many universities have formed or use existing foundations (for-profit or nonprofit) to receive and manage royalties from licensing agreements. In those cases in which the university participates as an equity partner in firms located in a university-supported innovation center, income is managed by a foundation and used to support the operation of the center to encourage the development of other technology-based firms. These buffer organizations remove the university from direct decisions with respect to company operations and minimize appearances of conflicts of interest or conflicts of commitment for university personnel participating in new companies. The Federal laboratories that are not operated by universities do not have foundations associated with the facility that can serve the same function. One Federal laboratory is presently structuring a cooperative research agreement that includes a for-profit corporation to fund the research effort and to receive any royalties resulting from commercialization efforts. However, the laboratory does not maintain an equity position in any of the participating industrial firms.

Antitrust Considerations

Antitrust laws are designed to protect consumers by restricting anticompetitive cartel activity. Industrial firms have been concerned that the U.S. Justice Department would view cooperative research ventures among competing firms as a violation of antitrust laws. There are substantial financial penalties for violations. With respect to government's concerns, William Baxter notes that the "principal concern is that competition among rivals will be suppressed through collusion," in three areas (see William F. Baxter, "Antitrust Law and Technological Innovation: in Issues in Science and Technology, Winter 85:80-91):

- the joint R&D effort may be used by competing firms for purposes of collusion,
- participation in the joint venture by a large number of potential innovators may reduce the industry's incentive to make substantial R&D investments, thus restricting innovation,

- markets for new products or services resulting from successful joint R&D efforts may be restricted if the joint venture is used for collusion in prices and outputs.

In 1984, Congress amended the antitrust laws to clarify the position with respect to cooperative research ventures, thus addressing many of industry's major concerns. The National Cooperative Research Act stated that joint R&D ventures should be judged under the rule of reason, rather than regarded as illegal <u>per</u> <u>se</u>. Antitrust damages are limited to actual rather than treble damages if the participating firms voluntarily disclose the nature of the relationship. The purposes for which cooperative ventures may be formed are also defined and limit the activities to precompetitive stages of research and development. Competing firms may participate in joint R&D efforts for the following purposes (P-L 98-162, Sec. 2):

- theoretical analysis, experimentation, or systematic study of phenomena or observable facts,
- the development or testing of basic engineering techniques,
- the extension of investigative findings or theory of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, prototypes, equipment, materials, and processes,
- the collection, exchange, and analysis of research information, or
- any combination of the above purposes.

The participants may not exchange information about sales, profitability, prices, marketing, or distribution that is not required to conduct research.

In order to qualify for the financial exposure protection, disclosure to the Justice Department is required. The Department reviews and evaluates the proposed venture from the perspective of the venture's effect on market competitiveness. The procedures are similar to those used in evaluating potential mergers and consider the number of competitors, the aggregate R&D expenditures of the participating firms in relation to the industry as a whole, and their aggregate market share. The Department has approved 54 joint ventures since 1984.

One of the particular advantages of a cooperative research venture for public institutions is that it provides a mechanism for combining the institution's intellectual property with a firm's manufacturing and marketing capabilities. The understanding of a firm's manufacturing techniques and markets is often critical to integrating a new or improved technology into the firm's existing capabilities so that innovation may occur as efficiently as possible. However, public research organizations and personnel should be aware in structuring cooperative research agreements that detailed information about individual firms may not be possible because of proprietary information concerns and also because of the antitrust provisions limiting disclosure of information about these areas in cooperative research ventures.

Industrial firms are sensitive to the appearance of collusion. Basic research can be conducted at a precompetitive stage, with product design and development pursued independently by individual firms. If the public sector laboratory is involved in the later stages of development that require access to a single firm's proprietary manufacturing information or marketing information, a later-stage consulting relationship will probably be required by the firm because of market considerations and antitrust laws.

Exclusivity vs. Nonexclusivity

The disposition of intellectual property resulting from cooperative R&D is an issue in the negotiating phase of structuring a cooperative research agreement. It is often assumed that a firm will not be interested in commercializing a technology without an exclusive license and that firms participating in joint R&D efforts with a university will insist on exclusive rights to resulting technology. This has been the case in a few cooperative agreements between a university and a single firm. In cooperative research ventures with competing firms (and in many agreements with a single firm), the university negotiates nonexclusive licenses to all of the interested participants. Nonexclusive licenses are acceptable to firms when basic research results are being transferred because the work has not resulted in a specific commercial product or process that the firm can market. The exclusive licensing of a laboratory's intellectual property is more likely to become an issue when the laboratory is involved with an individual firm working on a technology that is relatively close to being "market-ready." In this case, the primary concern of technology managers will be the terms of the license, including whether it is desirable to limit the license to a particular application, or "field of use," in order to achieve a wider distribution of the technology and to enhance subsequent royalty income. Federal laboratories are authorized to negotiate the full range of licenses (i.e., exclusive, partially exclusive, or nonexclusive). However, it should be remembered that with Federal technology, the government retains the right of use free from royalty payments because the Federal government is a major market for goods and services. An exclusive license as understood by private sector firms is not available.

Education and Training of Scientists and Engineers

The primary industrial motive for participation in cooperative research arrangements is to gain access to graduate students working in areas of interest to the firm. Many of these students will work for industrial firms as practicing engineers or as researchers. Others will continue research careers in the university system or in Federal laboratories. Thus, the type of education that students receive and the experience they gain in conducting research during the educational process is of critical importance to a variety of organizations in the public and private sectors.

For many years, industrial representatives have expressed concern that university students, particularly in engineering, are enamored of science and increasingly dissociated from industrial R&D methods. The differences in the nature of science and technology require different approaches to research and a different orientation among the researchers.

The orientation toward practical problems is difficult to gain in a university atmosphere that is permeated with scientific inquiry. Science within the university is generally concerned with knowledge for its own sake. The issues that are addressed are determined by peer groups. And the investigations are abstract, analytical, and specialized. Within industry, however, research is directed by company needs, which are concerned with product and process improvements and new products. Investigations require synthesis rather than analysis and interdisciplinary activity rather than specialization. These investigations must eventually lead to concrete particulars rather than abstract generalizations.

There is also a shortage of technical personnel in several important fields. Some major technology-based firms (e.g., IBM, General Electric, and Wang Computers) have formed schools to train people with skills that were not included in university curricula. The Massachusetts High Technology Council has been very active in suggesting curriculum changes in state engineering departments to provide students with a broader educational background (e.g., improved communication skills) and a greater appreciation of the application of scientific principles to general design problems. The chemical industry has also been active in promoting a greater understanding of techniques used in the industrial environment for chemistry and chemical engineering students (e.g., cost/benefit analyses). Given industrial insistence on both broader education and a more narrowly focused emphasis on practical techniques, industry seems to be calling for more of a balance between the needs of academic and industrial interests.

Cooperative research centers offer an opportunity to achieve this balance and to provide students and faculty with research opportunities of interest to academic researchers in a setting that is closer to industrial research environments. By conducting basic research that is both somewhat focused and multi-disciplinary, the environment existing in corporate research divisions can be approximated.

Engineering education is a special concern. The new NSF Engineering Research Centers are designed to strengthen the link between fundamental scientific research and application. The National Academy of Engineering endorsed the research center concept, pointing to the need for universities to be more responsive to the needs of practitioners. The industrial vision for these engineering centers is expressed succinctly by Roland Schmitt, General Electric's senior vice president of corporate R&D (see Roland W. Schmitt, "Engineering Research and International Competitiveness," High Technology, November 1985):

> The goal of industry-university interaction should be a two-way flow of information. From industry to universities should flow understanding of the barrier problems that practice is running into. From universities to industry should flow the knowledge and talent needed to overcome the fundamental problems. The main point is not to drive universities away from fundamental research, but to orient them toward the areas of fundamental research that are most needed by industry.

The industrial objective is not to redirect engineering research from basic to applied work, "but to do fundamental research in the areas of engineering practice being taken on by industry." Schmitt offers the following examples:

> The centers should not be building factory robots...but generating new understanding of the fundamentals of robotic vision, touch, and control; not programming expert systems for use in diagnostics or repair, but acquiring new understanding of knowledge representation and developing the fundamentals of artificial intelligence; not building biotechnology production facilities, but devising new unit-operations concepts for biological processes.

Schmitt concludes that the Engineering Research Centers should get students used to the idea that "the engineer does research in order to do, not merely to know."

SUMMARY AND CONCLUSIONS

Recent technological advances and highly successful product innovations accomplished by Japanese and European firms have focused the attention of national policy makers on the role of scientific and technological R&D in the innovation process. One of the primary objectives is to structure mechanisms that will bring the R&D resources and capabilities of the private and public sectors into closer harmony so that information and developments that occur in scientific fields may be used more quickly and efficiently by industry in the quest for new and innovative products, processes, and services.

Cooperative research efforts represent one of the several important mechanisms that has been encouraged by both the private and public sectors. Many of the Nation's most prominent research universities have initiated cooperative research agreements with industrial firms. The National Science Foundation has funded cooperative research centers to demonstrate Federal commitment and support and has provided assistance in the establishment and operation of many, but by no means all, of the joint research initiatives. The Justice Department has reviewed and authorized the formation of over 50 joint research efforts between competing firms since 1984. Many states have contributed funding to cooperative research ventures at state universities. The 1986 Federal Technology Transfer Act and subsequent Executive Order expand the ability of Federal laboratories to participate in cooperative research activities with industrial firms.

Although cooperation in joint R&D activities between public sector institutions and private organizations is relatively new, the initial evaluations performed by NSF of its university-based research centers indicate a positive response from universities and industrial participants.

There has been considerable academic controversy surrounding the cooperative research concept. The major issues concerning university personnel focus on the effect of industrial funding for research on the values and institutional integrity of the faculty's basic mission responsibilities, particularly teaching and the performance of disinterested scientific research. None of the primary faculty concerns (i.e., the open exchange of information and ideas and research independence) have emerged as significant factors in the operation of university-based cooperative research centers. Institutional problems related to conflict of interest and conflict of commitment have been resolved by university faculty and administrators largely within the existing structures.

Most of the university concerns are based on a fundamental misconception of the role that university research plays in industry's business strategy and what motivates industrial participation in cooperative research activities. There is a widespread belief on university campuses that industry is only interested in short-term, applied research intended to result in products and processes that will financially benefit the firm. This type of research and the approach required to achieve tangible results is in opposition to university research and methods of inquiry. The academic assessment of industrial interests is largely correct with respect to the reason why industrial research is conducted within a firm. The key distinction to be made is research conducted by the firm for its own use. Most of the firm's financial resources dedicated to research are concentrated in applied research areas. This must necessarily be the case because the firm's purpose is to create and market products and services.

It must be clearly understood that the primary reason for firms to participate in cooperative research activities is not to obtain technologies (that derive from applied research) but to gain access to promising graduate students doing research in scientific areas of interest to the entire industry. Many of these students will find employment in industry. Secondarily, the firms are interested in gaining access to leading scientific researchers to obtain advance information on research findings that may indicate the direction that a particular field of inquiry is leading. Consequently, the primary issues of concern to industry participants have focused on antitrust considerations of competing firms participating in joint research efforts, even at the precompetitive level of basic research, and the education and training of students, particularly engineering graduate students.

In practice, the cooperative research centers generally conduct basic research in areas of mutual interest to university researchers and industrial firms. Industry has proved supportive of basic research but expects the work to be conducted in broad areas that are related to the industry's products or processes. The cooperation of competing firms has precluded many of the universities' initial concerns that research would be redirected from basic to applied work. Independence is maintained by agreeing on a broad area of mutual interest. Individual projects are selected through a proposal (submitted by professors) process and evaluated by a board consisting of industrial and academic representatives. Publication of research findings has not been restricted, but has been delayed to allow time for the university to file patent applications. The university generally holds the patent and grants industrial participants nonexclusive licenses.

A second and equally important broad area of interest to universities concerns conflicts of interest and commitment. Conflict of interest refers to the standards set forth by various regulations and guidelines governing the proper conduct of employees with respect to financial gain from publicly-funded activities. These situations are handled in much the same way as standard consulting agreements, with disclosure of faculty activities as the key monitoring mechanism. The conflict of commitment issue (i.e., balancing industrial research relationships with faculty mission responsibilities) is also treated much like consulting arrangements. Cooperative research centers conducting basic research do not experience the conflict of commitment problem in general as a result of faculty selection of the research project and the inclusion of graduate students. These relationships are compatible with the university mission of teaching and research.

Industry has also expressed concern about maintaining the traditional value system of the university and the necessity for universities to engage primarily in basic research and teaching activities. However, an important issue for industry involves antitrust concerns related to the government's view of competing firms participating in cooperative research ventures. Although Congress has resolved some of industry's concerns with respect to antitrust matters, limitations on the type of interaction competing firms can engage in still exist.

The ability to hold exclusive rights to technology developed in cooperative research ventures is perceived as an industry issue; however, the university cooperative research centers primarily conduct basic research at a precompetitive stage. Application work, which would be more appropriate to exclusive licenses, is conducted in-house by individual firms. Thus, the university's preference for granting nonexclusive licenses to participating firms is acceptable to the participants.

A third important issue to industrial participants is the increased need for highly trained technical personnel. The primary motive for participation in cooperative research efforts is to gain access to graduate students doing advanced work in areas of interest to the firm. The nature of the education that future scientists and engineers receive is of great interest to industry, as well as to universities. Industry maintains that the educational process has increasingly shifted to emphasize scientific concerns rather than providing background and experience that would familiarize graduate students with the requirements of design and applications work. Cooperative research arrangements provide an environment that still concentrates on basic research (also needed by industry) but more closely approximates an industrial basic research unit by emphasizing multi-disciplinary (rather than individual) efforts in a focused research area of interest to industry.

Most importantly, it has been found that all of the issues can be resolved by focusing on the objective of cooperative research: to contribute to the innovation process. The successful accomplishment of this objective requires an alliance of basic and applied research skills in many disciplines and the capability to transform research results into marketable products and the processes used to make them. Faculty members can contribute most significantly by producing students who have an appreciation of academic and industrial research needs and by providing important information to industrial scientists concerning the direction leading academic research is taking. Industrial firms are better equipped to create, design, manufacture, and market technology-based products. An innovation cannot occur without research, design, production, and marketing capabilities provided by industrial firms.

Cooperative research activities between Federal laboratories and industrial firms provide an appropriate mechanism for the laboratories to engage in more active technology transfer activities. The issues that have concerned university researchers should not become major issues for Federal laboratories. Most importantly, the Federal laboratories have clear authorization to engage in cooperative research activities and are strongly encouraged to so so by Congressional legislation and Presidential Executive Order. Thus there is no basic conflict of commitment. Most conflict of interest questions for faculty personnel can be resolved on a case-by-case basis according to existing statutes.

The remaining potential conflict of interest problem is with equity positions in companies based on laboratory technology and thus far has involved the status of contractors operating Federal laboratories, rather than personnel equity positions. Potential personnel conflicts of commitment can be resolved through personnel management procedures established in laboratories.

For laboratory personnel funded through cooperative research ventures with industry, equity positions are not involved and therefore do not represent a potential conflict of interest. Conflict of commitment is unlikely because most of the research that industry will be interested in will probably already be in progress in the laboratory as part of agency-funded research.

The experience of university-industry cooperative research centers indicates that participation by industry will not preclude publication, but may delay publishing until the laboratory files for patents, if appropriate. Arrangements with individual firms, however, may involve proprietary information and the need for exclusive licenses, thereby restricting publication, depending on the nature of the work and its results.

The Federal laboratories offer advantages over universities in some areas of working with industry. The laboratories conduct exploratory and development research and are also involved in demonstration projects. All three are areas that would be appropriate to joint laboratory-industry cooperative research ventures. Many of the laboratories conduct large multi-disciplinary scientific or applied research projects. This environment more closely approximates the industrial setting.

The laboratories are primarily limited by industry's primary interest in access to students. Many of the laboratories, particularly those located at university campuses, can and do encourage faculty members and their graduate students to use laboratory facilities and conduct joint research activities. A collaboration of Federal laboratory-university-industry participants (including graduate students) could provide research and education of interest to industry and benefit all of the participants.

Issue Paper VI

INTELLECTUAL PROPERTY AND TECHNOLOGY TRANSFER

Issue Paper VI

INTELLECTUAL PROPERTY AND TECHNOLOGY TRANSFER

Gellman Research Associates, Inc.

INTRODUCTION

There are several types of laws that govern the ownership of property. Personal property law determines the ownership of things. Real property law deals with the ownership of land and buildings. Intellectual property law determines the ownership of the particular form or expression embodied in things. Intellectual property rights are secured by patents, copyrights, trademarks, and trade secrets. Patents and copyrights are characterized by the grant of a limited monopoly power to the inventor or creator, and their main purpose is to stimulate and promote the progress of science and the useful arts by giving the inventors and authors an opportunity to make profits from their respective inventions and writings.

Article 1, Section 8, Clause 8 of the U.S. Constitution grants to Congress the power 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 very general mandate is the foundation for a complex set of laws and regulations involving the property rights that are given to inventors and authors.

The U.S. Government plays a central role in the development of science and technology. Not only does the government create and regulate patents and copyrights, but the government directly funds extensive research and development aimed at advancing science and technology. In the latter role, the government itself often patents its own inventions in the same way a private individual or corporation would.

Several recent laws have consolidated and changed the government's policy toward the technology it creates and owns. Incentives are now provided for stimulating innovation and transfer to commercial uses of inventions made at both government-operated and contractor-operated Federal laboratories.

This paper will focus on the legal protections afforded intellectual property. It also raises and discusses the business and legal issues inherent in the transfer of intellectual property from the public to the private sector.

THE PROTECTION OF INTELLECTUAL PROPERTY RIGHTS

A discussion of the legal forms of protecting intellectual property rights must be part of any review of the transfer of intellectual property from the public to the private sector. Each of the four legal forms for protecting intellectual property (patents, copyrights, trade secrets, and trademarks) are discussed below. However, this paper focuses primarily on patents, as they are the most important from the perspective of a government R&D laboratory manager.

Patents

A patent can be issued upon application if its subject matter is a new, non-obvious and useful process, machine, manufacture, or composition of matter, or any new and useful improvement. (35 USCA 101). The primary purpose of the patent system is to promote the progress of "science and the useful arts." A secondary purpose is the reward of inventors. In return for a limited 17 year monopoly, the inventor agrees to make public the information about his invention with the stipulation that the invention is in the public domain after the patent expires. In the United States, patents are issued by the Office of Patents and Trademarks of the U. S. Department of Commerce.

Patent laws in the United States allow a one-year grace period in which a new invention can be introduced into public use (as in publication) and still qualify for a patent (assuming all other requirements are met). However, the application must be filed within that one-year period following publication. In order to be an effective bar to a patent, the publication must furnish enough details as are necessary to determine the practical working of the invention. Beyond the grace period, no valid patent will be issued in the U.S.

This can be extremely important to remember for government and university project managers since there is a bias in these institutions toward publication of research results rather than toward producing commercial products. In the not-for-profit sector there is no economically useful equivalent of "proprietary data" (trade secrets) as there is in industry, and historically patents have been the only effective means of protecting inventions. Given a tradition of publication, many patentable ideas can be lost during the one-year grace period between publication and patent application without heightened awareness of the risk.

Copyrights

Copyright protection subsists ". . .in original works of authorship fixed in any tangible medium of expression, now known or later developed, from which they can be perceived, reproduced or otherwise communicated, either directly or with the aid of a machine or device. . ." [17 U.S.C. 102(a)]. A copyright is issued for the lifetime of the author plus an additional 50 years, or, in the case of a corporation, for a total of 75 years.

Copyright protection does not extend to any idea, procedure, process, system, method of operation, concept, principle, or discovery, regardless of the form in which it is described, explained, illustrated or embodied in such work (17 USCS 102 (a), et. seq.). These types of intangible property are instead candidates for patent protection.

Copyright protection is available for computer programs. However, some computer programs, or parts of them, can also be patented. A discussion of the problems inherent in this very complex and developing area of law are discussed in a special section below.

Trade Secrets

"A trade secret may consist of any formula, pattern, device or compilation of information which is used in business and which provides an opportunity to obtain advantage over competitors that do not know or use it. . ." [Restatement of Torts, 757, Comment (b)].

Trade secret law is substantially different from patent and copyright law. Each state in the U.S. defines what constitutes a trade secret and what rights the holder of the trade secret has. (Patent and copyright laws are defined by Congress and enforced in Federal Courts.) Unlike copyrights, trade secret protection can extend to the ideas, algorithms, and procedures embodied in a program, as well as to the expression adopted by the programmer. Unlike patents, trade secrets generally require no compliance with formalities, no waiting time to acquire, and no proof of novelty or non-obviousness. A court ruling upon a trade secrets case will look to the unique value of the secret to a company's competitive advantage and the effects of a disclosure of the secret on a plaintiff's business, and the contractual or tortious misdeeds of a defendant. In contrast, a court in a patent or copyright case will focus on strict standards of infringement (Intellectual Property Rights in an Age of Electronics and Information, Congress of the U.S., Office of Technology Assessment, April 1986, p. 87).

In the public sector trade secrets are not a good substitute for patents and copyrights, because they discourage the publication and dissemination of information. They are often characterized by employment contract clauses and may restrict the ability of employees to "spinoff" and form new companies which might then compete with the older company. Defending a trade secret in court can also be very costly and time consuming, and the legal requirements to successfully defend the secret may involve revealing the information a company wants to keep close.

The three legal forms of protection just described are compared in Table VI-1.

Trademarks

A trademark is a sign, device, or mark by which the articles produced or dealt in by a particular person or organization are distinguished or distinguishable from those produced or dealt in by others. The Lanham Act (15 USCS § 1127) defines the term trademark "to include any word, name, symbol, or device or any combination thereof adopted and used to identify goods or distinguish them from others."

Statutory Invention Registrations

Of particular interest to government laboratories, but available to anyone, is the Statutory Invention Registration (35 U.S.C. 157). This is a new mechanism (1984) created by Congress which amounts to the formal publication of an invention and thus prevents anyone else from patenting the invention. In order to qualify for a Statutory Invention Registration, an inventor must meet the specification requirements for a patent and waive any fees. The inventor fills out a regular patent application, but it is never examined by the Patent Office. The inventor is not entitled to any legal remedies for the infringement of a patent.

Table VI-1. Comparison of Legal Forms of Protection

Consideration	Copyright	Trade Secret	Patent
National Uniformity	Yes	No	Yes
Protected Interest	Fixed expression of author	Ideas and expressed	Invention
Scope of Protection	Exclusive right to reproduce, prepare derivative works, publically display and publicly perform	Exclusive right to use	Broadest, excludes others from making, using, selling
Effective Date of Protection	Fixation of work in sufficiently permanent and tangible form	Use in Business provided that subject matter is guarded from public disclosure	Issue of patent successful prosecution of patent application
Cost of Obtaining Protection	Small	Moderate	Moderate
Term of Protection	Life of author plus 50 years or 75 years	Possibility of both perceptual protection and termination at any time	17 years
Cost of maintaining protection	Small	Significant	Nil
Cost of Enforcing Rights Against Violators	--	Moderate	Very high
Protection lost by. . .	Gross neglect	Public disclosure	Unsuccessful validity or misuse litigation
Internationally	Often	Not generally	Often, but foreign filing may disclose before U.S. rights perfected
Execution of softwater products protectable	No	Yes	Yes
Suited to wide-scale distribution	Yes	No	Yes

Source: Sheridan, James A. "Patent Protection of Computer Software--Practical Insights" (23 Santa Clara Law Review 989-1000 [1983]).

Licensing

A license is the granting of the right to use a patent from a patent holder to another party. The grant frequently involves the payment of a royalty (individually negotiated, but usually as a percentage of sales, or a fixed amount per sale) to the patent holder from the licensee.

A patent, as described above, creates a measure of legal protection for an invention. This protection can have tremendous economic value to the firm, the individual, or to the government. First, a patent has "exclusionary value," permitting the patent owner to exclude others from making, using, or selling the patentable invention for a period of time. This power might also be used in a negative fashion--to deny the invention from the commercial marketplace.

Second, the patent may have "pecuniary value." This is the value it has as a marketable good in and of itself; often a patent can be sold, licensed, or used to acquire rights to other patents (sometimes through cross-licensing).

Finally, and of particular importance to the government when it acquires a patent, it has "immunity value." This permits the government to reduce or eliminate costs in connection with government production or procurement.

Since the patent affords legal protection to an invention, the patent in itself represents some of the potential value of that invention (i.e., that part that is protected in geography and time by the patent). The value is determined in the marketplace by the ability of the patent holder or assignee to make use of the invention in a profitable way, and by the income that can be realized from the sale of some or all of the rights to make, use and sell products and services through exploitation of the invention.

For a variety of market, product-line, and strategic reasons, a patent might be worth more to another firm than to the patent holder. In this case, it is common to license the invention. Licensing, therefore, is a business decision revolving more around practical financial concerns than around technological issues.

Licensing of Government Inventions

When inventions are owned by the government, public policy considerations have played a considerable role in handling decisions about licensing to the private sector. A policy of granting only non-exclusive licenses was common in many agencies until fairly recently. The reasoning was that since tax dollars paid for the R&D and the technology, any citizen should be able to use the technology for the asking.

Licenses can be exclusive or non-exclusive. Generally an exclusive licence prohibits the commercial use of the invention by anyone but the licensee. A non-exclusive license permits the owner of the invention to allow more than one person or corporation to use the invention. In the private sector, the degree of exclusivity of a license is negotiated, and royalties and other monetary considerations are agreed upon at arms length between the parties involved.

More recently, the trend has changed toward the issuance of exclusive licenses for government-owned technology. Since significant capital investment often must be made to further develop the technology and then to produce and market it, companies were reluctant to invest the required amounts without some guarantee of property rights. Recognizing that the benefits of new technologies in the marketplace include job creation, productivity improvements, and a better quality of life, the government has changed its policy and now encourages the granting of exclusive licenses on its technology. Nevertheless, the decision process is quite different from that of the private sector in licensing. For the government, the key factors are the dissemination of the technology and the public and economic benefits to as many people as possible. And, at least in the case of domestic licensees, income from the technology is of secondary importance. For the private corporation, licensing is a way to profit from the ownership of technology, and the revenue realized from the license is critical.

THE RECOGNITION OF COMMERCIAL POTENTIAL

In keeping with the revised government attitudes toward transfer of technology to the private sector, the government manager must develop a sensitivity to the potential commercial applicability of a particular intellectual property.

Inasmuch as most government technologies have little or no immediate direct application to commercial products, managers are not accustomed to being sensitive to market trends and potential. Even in the industrial world where research is more often market-directed, it is very difficult to accurately predict the marketability of the technological innovation. Many factors come into play in an evaluation of the potential value of new technology, and most of them change over the course of the development of an idea into a final product.

A technology that may be revenue-producing for one firm may not be for another. Finding the proper match at the proper time in the life-cycle of the technology, in the marketplace, and in the industry, to effectively transfer the technology can be a very difficult and complex task. But how that task is carried out may determine which government-owned technologies are successful in the marketplace.

It is therefore important for the government manager to begin to evaluate ideas as they progress from research into applied stages. Understanding that internal government mechanisms may not exist to explore related market and industrial developments, commercial evaluations of the technology should be considered. It is important, too, to involve government counsel early in the process, especially if a commercial application is suspected, perhaps warranting early protection.

The Business Viewpoint

New technologies represent potential value to business enterprises. For a business, a new process or product can gain a market or competitive edge, and it can generate increased profits through the more productive use of input resources or through increased sales. The bottom line for the private sector is profits. But the decision to invest in new technology also involves risk and uncertainty. Will the technology perform as hoped in large scale production? Will the market demand for the product be robust and live up to expectations? Will the property rights (patent, copyright) granted to a new technology be sufficient to protect the company's investment?

Firms analyze new investments on both the ability of the investment to generate cash flow and profits, and on the "opportunity" costs of a particular investment when compared to other alternate uses of the resources. For the investment to occur, the projected net returns to the project (on a discounted cashflow basis) must be positive and higher than other investments. These criteria have important implications for new technologies. A technology must be at the stage in its life-cycle that permits this type of business analysis. If the transfer is made too early in the development of the invention, the risks, both technological and market, may be so great that projected returns are either low, or too far in the future to appear profitable from a discounted cash flow methodology. In addition, there is the risk of alternative inventions filling the market before the invention in question can be perfected, and there are risks that the market may sufficiently change so that the projected demand curves never materialize. There is also the risk that the supply prices of necessary inputs to production may change significantly.

On the other hand, if the transfer is made too late in the development of the product, the flexibility of the firm is limited in its ability to alter the product to meet near-term changes in the market. In addition, a significant amount of additional investment is frequently needed to establish a distribution and marketing network for the product. In the case of entirely new goods or services (either to the economy or to the firm desiring the transfer), these costs can be very high.

Business is not as interested in the technology as a "neat item" as it is the inherent value that the technology represents. Often in government laboratories, the completion of a mission requires very advanced technologies to be developed. Although development cost is a factor in government budgets, and purchase price is very significant in the ultimate use of the technology for mission purposes, performance is most frequently the government's "bottom line" criteria. Government managers involved in technology transfer activities must always remember that the goals of business are different, and that the transfer of technology to business is done on private sector terms, not government evaluation terms.

Other considerations of a businessman in pursuing a new technology are whether to develop and market the invention themselves, or whether to license someone else to produce the product (assuming they have the property rights), thereby reducing their own investment and market risk. It is possible for a firm holding the technology to license one or more companies, depending on the demand and needs of the market and their negotiating powers.

Additional issues include whether the technology is a product of supply-push or demand-pull forces. With supply pushing technology (as in many government developed inventions), the demand must be created to meet the new product. This can be a very long-term and expensive process. With demand pulling the invention, the potential near-term sales are much greater since the product was developed to meet a particular need. Demand-pull has its own set of risks, because by the time the development and distribution networks are in place, the product may have already become outdated. In other words, correct timing is crucial to successful transfers of technology.

Property rights are also important. Without some form of ownership, it is very difficult to convince investors to lend money or put up equity in a new, and risky, venture. As has been discussed elsewhere, obtaining these property rights has a cost--publication and disclosure.

Therefore, the type of invention to be transferred is very important. Its degree of "imitatability" or "stealability" has to be considered. Although black box reverse engineering is frequently too expensive and time consuming to be viable in the commercial market, it may be a real threat for relatively simple products that are near substitutes for existing ones. There can also be a great deal of difference among technologies and industries. In pharmaceuticals and chemicals where a patent is obtained, the ability to imitate or copy a compound may be easy, but the compound is so clearly described in the publicly available patent data that enforcement of the patent protection is also relatively easy. But for mechanical and electronic components, "inventing around" the patent may be possible, and patent infringement cases more difficult to prove.

The expected life-time of the product is also important. In a fast-paced industry such as electronics, today's technology may be outmoded in a few short years. The patent process takes time. By the time a patent is issued, the value of the protection may be greatly diminished, and the firm may find that form of protection is not worth the effort. It is sometimes better to be several steps ahead in technology development than to be constantly spending effort and resources to defend old technologies.

In summary, the business judgments that enter into investments in technology, whether in the company's own products or in the potential to purchase technology from another company or the government, are the important factors in valuing and successfully transferring technologies. Cost and time are essential to the process, and government managers must be very sensitive to government policies and priorities as well as to commercial needs. These needs are not the same, except for the very narrow area where some candidate technologies developed by or under government aegis are found to have commercial uses, and the government itself has taken the initiative to develop that product for commercial purposes.

The most important considerations in transfer activities are the potential value and profits the technology holds for a business, the timing of the transfer, and the time it will take for the technology to yield a return from the business firm's investment. These criteria set the basis for the individual and complex negotiations that must occur in the transfer process, and also set the basis for the legal form of the transfer (patent, license, type and extent of royalties, restrictions, etc.).

The Decision to Patent

When a business is considering what to do with an invention, it must evaluate the invention against several variable criteria. What it does depends on a variety of factors, each of which may be unique to the particular invention, firm, industry, national economy, and international competitive position. It depends, too, on the technology itself, whether it is a product or process and where it is in its development cycle. It also depends on the overall growth rate of the industry and on the ability of a firm to maintain its competitive lead. Another consideration is the risk that the public disclosure required by patent law will lead to another firm inventing around the patent. Legally, it depends on the chances of qualifying for patent protection, the risk of successful downstream challenges to the patent, other available protections, and the cost in time and resources of pursuing the legal process.

A government manager has to consider similar criteria. He must be sensitive to a business' concerns in the technology transfer process, if transfers are to be successful.

Traditionally, the commercialization of an invention has not been the only reason for the government seeking patents on its inventions. Other reasons have included rewarding employees for excellence and protection of a technology for defensive purposes. However, Statutory Invention Registrations, created by Congress in 1984, are intended to be used to reward employees and to provide defensive protection for inventions, without the government having to incur the high costs of patenting. Patenting would be researved for those inventions that exhibit commercial potential.

INTERNATIONAL INTELLECTUAL PROPERTY

A number of international agreements have been negotiated which provide minimum protection for copyrights, patents, and trademarks of member nations. These agreements facilitate more uniform definitions of patents and provide for centralized filing procedures and standardized application formats.

Guiding principles of these conventions are that national treatment of intellectual property will be adopted. That is, any judicial decision concerning a patent will be made in the country where the rights holder seeks protection, regardless of his nationality. Nations are still free to set their own levels of protection according to their social norms. However, each member nation has agreed to a common set of minimum rights to be granted to foreigners. This has had the effect of increasing the levels of international protection.

However, not all nations are members of each convention, and just because a nation is a member of one or all conventions does not mean that a patent or copyright in one is valid in every other member nation. In order to protect intellectual property, filings in other nations are required, and the specific laws and regulations of those countries rule.

In general, a United States patent only protects the invention within the geographical borders of the United States. In order to obtain protection for the invention in other nations, a separate patent application must be made in each country for which protection is desired.

A full explanation of the intricacies of patenting in other nations is well beyond this issue paper. However, an example will illustrate the complexity of dealing with these various laws. In Europe there is no one year grace period for publication as there is in the U.S. An invention is either disclosed or not disclosed. Therefore, if the U.S. inventor publishes the invention and still qualifies for a U.S. patent, he may have precluded the invention from an European patent. On the other hand, in Europe an inventor can qualify for a patent if the applicant uses the invention only for his own commercial purposes (unpublished and not for public sale), even though he has kept it as a trade secret for more than a year. In the U.S., this would prevent his ability to get a patent on that invention.

Many other legal complications can occur in the international framework. For instance, if a patentee owns both a U.S. and a foreign patent on the same invention, the patentee may couple his sales of the invention in any foreign country with a restriction that precludes the importation of that invention into the U.S.

In short, a patent, by definition, is limited to certain territorial rights. Since patent laws vary greatly among nations, specific advice concerning foreign patenting should be obtained at an early date (before publishing the results of patentable inventions) from legal experts.

JOINT RESEARCH VENTURES

Central to most joint research ventures is an agreement concerning the ownership of the intellectual property that results from the venture. The key public policy issue is the balance between potential anti-competitive aspects of commercial joint ventures and society's benefits from new technologies that result from the venture.

Joint ventures may involve patent interchanges (including cross-licenses) at initial stages of the research. For example, if one firm owns a strategic patent in a particular area that another firm wants to do research in and the first firm "blocks" the research by refusing to license the technology, there may be grounds for establishing a joint venture to free-up the blocked patent. Or the joint venture may be based solely on a financial need to combine resources, to diffuse the risk involved in particular research. In this type of venture, the patent and license questions concern the results of the venture.

In general, joint ventures are encouraged, particularly those that deal with basic research where the results of the project are more likely to be ideas and inventions that need much further work before commercial products will result. However, any joint venture that involves intellectual property exchanges includes some risk of running afoul of antitrust policies. The joint venture generally will not be considered anti-competitive if the scheme:

1. Does not insulate a patent from attack based on invalidity;
2. Does not dominate an industry;
3. Does not create cartels in a market;
4. Does not set market prices;
5. Does not reduce quantity produced; or
6. Does not otherwise regiment the marketplace.

In addition, territorial restrictions are looked at closely, remembering that any patent grant includes national territorial restrictions. If research is the reason for the joint venture, then usually there is no problem. Once commercial products are involved, the tests become more complicated, but the key tests center on the agreements to license the inventions outside the firms involved. If the firms doing the research make up a significant share of the market (national or international), then it is incumbent upon the firms to have a liberal licensing policy, at least among the partners involved.

In summary, collateral restraints involving patents and knowhow are permissible under various rules of reason. If the restraints are incidental to an objective that is lawful (e.g., research), and if the scope and duration of the restraint is reasonably required to achieve the objective, and if the restraint is not part of an overall scheme or pattern of agreements that has anti-competitive effects, then the restraints will be legal. Basic research rarely creates problems in this area; legal tests are more often concerned with the marketable commercial products which are the fruits of research.

PROTECTION OF COMPUTER SOFTWARE

Computer software is of increasing importance in today's world. Both government and private research efforts to develop new software represent the cutting edge of the growing computer and electronic industries. Software development is necessary for strategic and commercial leadership over the coming years. However, software as a commodity presents a very significant problem because it can be considered both as patentable and as copyrightable. The legal treatment of the ownership rights to software is still far from being reduced to a set of well established precedents.

So far, the courts have generally limited software to the less desirable (from an industrial and competitive protection standpoint) copyright standard. To the extent that the tangible part of software is the computer disk on which programs are written, it is analogous to motion pictures and audio and video tapes. But to the extent that it represents new, unique, and non-obvious ways of performing tasks, it could be considered for patent protection.

There have been some recent notable exceptions where the courts have allowed patent protection for computer software. The distinction between what is patentable and what is unpatentable under 35 U.S.C. 101 was determined over 130 years ago in O'Reilly v. Morse (56 U.S. (15 How.) 62, 131 (1853)). To quote:

> The mere discovery of a new element, or law, or principle of nature without any valuable application of it to the arts, is not the subject of a patent. But he who takes this new element or power, as yet useless, from the laboratory of the philosopher, and makes it the servant of man; who applies it to the perfection of a new and useful art, or to the improvement of one already known is the benefactor to whom the patent law tenders its protection.

The discussion of computer software revolves around whether it performs an algorithm or not. If an algorithm does more than represent a scientific principle or law of nature, and becomes a vehicle for communicating a solution to a complex problem in a particular environment, then its use can be the basis for patent protection (Diamond v. Diehr, 450 U.S. 175 [1981]).

The Court of Customs and Patent Appeals developed a two-part test to determine the patentability of software. The first step is to determine whether an algorithm is either directly or indirectly recited. If so, then the second step is to determine whether the claim would preempt the algorithm's use by anyone for any purpose. If so, then it fails to be patentable under 35 U.S.C. 101. But if the claim recites a calculation which is imminently related to the environment in which the invention is used and controls a process or transforms an article, it should be protectable by patent. Therefore, legal guidelines exist for patent protection of software, even if there are technical exceptions and still-evolving legal theories. (James A Sheridan, "Patent Protection of Computer Software-- Practical Insights," 23 Santa Clara Law Review 989-1000 [1983].)

Legal theory aside, the business and practical economic decisions about when and if applying for a software patent is desirable are quite similar to the decisions facing any new technology. These issues have been discussed in other sections of this report.

CONCLUSIONS

Technology itself is not really the issue in the transfer of inventions from the public sector to the private sector. It is the use of the technology and the value that the technology holds in the marketplace that is really of interest to business. Each technology in every industry and every firm is different. The degree of protection needed and granted by the patent is likewise different. From the strong protection that chemical and pharmaceutical firms may have in patents (each chemical compound is unique and therefore copies can successfully be challenged in the courts by the patentee), to the relatively weak protection in industries that are fast changing and where product differences are easily invented around, companies vary in their desire to patent their technologies.

Therefore, each example of an idea that represents potential value to the government, to a firm, or to an individual must be evaluated individually, just as each contract and patent license must be individually negotiated. There are no easy rules that carry over all industries and all technologies for government managers to follow in deciding how to act on new technology. It is an art, a feel for the idea and its potential that is important. Because there are no general rules, and because mistakes in publication and dissemination of information to the public can significantly impair the ability to obtain property rights at a later date, early conservatism on disclosure may be warranted. This is particularly true in the atmosphere that exists in government and academia, where publication is more often given priority above any possible commercial potential.

However, because one statutory objective of government research results (absent any national security issues) is dissemination of information, a delicate balance must be reached by government managers. This is most likely best done by early sensitivity to the issues and by the active interaction of technical managers with legal counsel and economic and marketing experts. If in-house capabilities are not present, then external advice is essential. It is only through effective use of resources from many areas that effective transfer of technologies from government to the private sector can take place with both a minimum of delay and a maximization of benefits to society.

Issue Paper VII

CLASSIFICATION SYSTEM FOR TECHNOLOGY

Issue Paper VII

CLASSIFICATION SYSTEM FOR TECHNOLOGY

Gellman Research Associates, Inc.

RATIONALE FOR A TECHNOLOGY CLASSIFICATION SYSTEM

The task of identifying and tracking technologies which may have commercial viability is a complex one, made even more difficult for the non-business-oriented person. As a response to the Congressional mandate that ". . .Technology transfer, consistent with mission responsibilities, is a responsibility of each laboratory science and engineering professional. . .", this paper represents an effort to make such tracking easier, or at least more systematic.

To simplify the task, a technology classification system has been developed. This system, outlined here as a modifiable set of data elements, can serve to permit managers to:

1. Identify and track technology developments in the process of innovation;
2. Make comparisons between alternative projects that are competing for limited funds;
3. Identify opportunities and management problems related to bringing technology into the market;
4. Concentrate resources where they are most needed to further the development and appropriate transfer of the technology;
5. Crystalize plans, ideas, and critical paths to support travel along each technology;
6. Indicate effective ways to market the technology as well as alternative approaches should an earlier one prove infeasible; and
7. Develop a perspective on the "portfolio" of technology the organization manages.

A suitable classification scheme clearly has to serve various purposes and meet the needs of myriad participants in the process of innovation. The classification system can be thought of as a tool to be used to enable managers to become more sensitive to critical technology transfer issues. Such a system can also enhance the organization's technology transfer performance by providing a framework for the process of taking an idea or invention and transforming it into a product or service that can be introduced into commercial use. Managers and the technical staff should be encouraged to use the system not only for specific data, but also as a means of gaining a broad perspective of the innovation process.

There are dangers in adopting a classification scheme that is too rigid. One that is too complex and requires too much information and professional time will be ignored, include unreliable information, or become an end in itself. Clearly any system should facilitate the active tasks of generating and transferring technology, rather than become an exercise in gathering information and filling out forms.

Four major objectives in a classification system are:

1. To promote understanding of the technology in terms of science, technology, and of the market(s) it can serve;
2. To support the description and understanding of the technology needed for intellectual property protection and transfer;
3. To support actual marketing of the technology, especially to entities outside the initiating organization; and
4. To encourage the effective management of each technology project and of the portfolio of all technologies available through the organization's activities.

BASIC CHARACTERISTICS OF A CLASSIFICATION SYSTEM

Technology appears in many forms. It can be an idea or concept and therefore abstract and not tangible in any sense. It can be embodied in a physical invention, a new product, or an intermediate process or improvement. It may be reflected in a management or organizational innovation, or by the incorporation of new software or routines that affect production or marketing.

Where possible, existing information classification systems should be used, and at a minimum, use of standard classification categories should be encouraged to facilitate the incorporation of existing information. For example, fundamental research being conducted within scientific disciplines is one breeding ground for new inventions. The research may take place in universities, government laboratories, industrial concerns, or not-for-profit entities; it may occur in the

United States or abroad. There are existing classification schemes for each of these disciplines, organizations, and industries. Where practical, they should be used for classifying technology, eliminating or diminishing the need to construct a new system.

The classification system should also be organized to facilitate the flow of information from data bank to user. There is no way to place priorities on the different methods of classifying technology because their importance varies with the user. Therefore, a system must be versatile, flexible, and "user friendly."

The classification system should reflect the diversity, complexity, and interactive nature of the "events" of discovery, invention, innovation, and marketing. The uniqueness of any given technology and its setting in government or a corporation must be emphasized by the information developed through use of the classification system.

Although the significant types of information that such a data and management system should incorporate and the probable uses of the information can be outlined here, it should be emphasized that not all of the information will be useful, available, or necessary to all technology managers. Each organization has to select carefully the information most appropriate to its own needs.

Not every technology needs to be documented and put into the system in the same degree of detail or in the full format. It may be that early evaluation determines that a particular technology is not commercially viable in the near term, or perhaps is subject to national security restrictions. In these and other cases, the documentation process may be suspended or delayed until conditions change. Early interaction between the developers and users of the technology (industry or government) will greatly simplify and expedite decisions related to the level of detail that is required.

Finally, data gathering and use of the system is a continuous effort; technological and scientific knowledge is always in flux. Overall economic conditions are also constantly changing, as are domestic and foreign markets for each and every good and service. In order to use the classification system to its best advantage, it must be kept up to date, and should be viewed in conjunction with external conditions that affect the organization's transfer efforts.

A TECHNOLOGY CLASSIFICATION SYSTEM

Discussed below are suggested elements of a technology classification system. In general the information contained in the chosen elements should be able to be used by managers to:
(1) appropriately understand and describe a particular technology;
(2) manage the organization's technology portfolio; and (3) market the technology.

A comprehensive understanding of the technology is required of people involved in the technology development and transfer process. The description of an innovation helps the manager to place the technology in its proper context for evaluation and management. In many cases, just the exercise of gathering the data for a description and organizing it in a logical framework may give managers valuable insights into a technology's future.

In the management of innovation portfolios, many budget, financial, and strategic decisions must be made in order to value the technology and select among the available options to accomplish the transfer. The recommended attributes identify the development costs, invested resources, expected future resources, private contribution to the development process, and a variety of other economic factors affecting the transfer. As a technology reaches the final development stages, many important negotiations occur, including the valuing of intellectual property rights and future income flows from commercial uses. It must be noted that the invested resources, particularly those made for government mission purposes, may bear little relationship to the value of the technology in the market, as the market value is determined by the supply and demand for the good or service--not by the amount of invested resources.

It is also important to compare the financial information for one technology (and that of other similar technologies) to the financial resources that will be required to complete development and transfer.

Finally, any suitable technology must be marketed to end users. A thorough knowledge of the demand for the technology (either mission related or commercial prospects) is required to successfully transfer a technology. Alternatives to using the technology, the expected relationship between the price that could be charged for the technology and the amount that can be produced, and a good indication of the financial arrangements that can be negotiated (e.g., licenses and royalties) based on the stage of development, must be evaluated in determining an acceptable value.

ATTRIBUTES OF THE TECHNOLOGY

A classification system with the 13 attributes described in detail below provides a broad framework in which to organize information, efficiently monitor a technology's progress, and facilitate management decisions. Together the attributes provide a profile of a technology, and a basis upon which to begin to evaluate its commercial viability.

1. The Science and Technology Underpinning and Requirements to Complete Development

A complete description of the technology requires a thorough and accurate identification of the scientific and engineering principles upon which the technology is built. Included in this description will be precursor innovations and technologies as well as information about the relevant basic research results.

Estimates of the future science and engineering requirements to perfect the technology and bring it to either mission-related use or final commercial use should be included where possible. These estimates will be useful in developing or managing the organization's technology portfolio. They will also become an integral part of the budget/financial analysis to determine near- and long-term investments required for final development.

2. History of the Technology

A complete chronology and documentation of the technology development has to be subdivided into various parts. One important segment is a documentation of where the initial impetus occurred. Examples of possibilities include:

- Part of a mission-related project;
- Basic research in a discipline;
- Suggestion of a contractor;
- Application or spin-off from another project; and
- Joint research effort.

Included in this history should be an accounting of the sources and application of funds for the project in as great detail as time and existing records permit. This information may be vital in determining ownership and provides a mechanism for distributing royalties based on R&D contribution.

Identifying the place where the actual work was done, what was done where, and when it was done are also very important to a complete description of the technology. In particular, distinctions should be made concerning the contributions of government laboratories, industrial concerns (if so, what firm and where), universities, and not-for-profit firms. Whether the work was done within the United States or by foreign entities can also be significant.

Tracing any ownership or proprietary rights that may flow with the technology is important for both portfolio management and for marketing the technology, as these rights may affect downstream licensing negotiations.

3. Process of Innovation

The process of innovation has been described in many ways. The most common is to trace the technology from its roots in scientific principles discovered from fundamental research, through various stages that include basic and applied research, to the development process leading to a prototype, testing, and eventual market introduction. This logical sequence of events may represent the "typical" path for particular technologies. However, the amount and degree of interaction in the process can be very great. Research may lead in many directions. There may be very little relationship to the logical sequence for many technologies. Some may jump very quickly from basic principles to a final product. Others may, during the development stage, lead to suggestions that lead to new scientific breakthroughs. In other words, the process of innovation may be random, may involve many forward and backward steps, and the outcomes may bear little relationship to the initial expectations.

However, it is still quite useful to describe technologies by the "pipeline" process, because the planning process for the development of a new technological innovation requires the commitment of financial and human resources. A logical and step-wise process is the framework for starting the process. As development progresses, changes can be made when the particular technology deviates from the model. Identifying the technology's development stage is useful in describing the technology, managing the portfolio, and marketing the technology. Of equal importance for descriptive and planning purposes is a knowledge of whether the final outcome is expected to be a product or a process.

Innovations may lead to a variety of outcomes. New products in the marketplace that make life easier, better, or just different are the most obvious examples of technologies that have been successful. Of course, not all new products are directly tied to formal technological development programs, nor are all new technologies successful in the marketplace. Personal computers, energy-efficient furnaces, "smart" appliances, microwave ovens, and graphite-composite tennis racquets can all be attributed to R&D efforts coupled with successful distribution and sales and effective market penetration. (And, in many cases the government laboratory has had a significant role in the development process of these products, albeit unintentionally.)

Equally important are the new process-related components. These are improvements in the way industry makes goods and provides services. They may be in the form of products similar to those that are for final consumption by individuals (e.g., the personal computer), but they are primarily used in further production. These innovations can be very simple, such as new forms of machine seals or gaskets or new lubricants, or they can be very complex, such as a new process for manufacturing steel. In addition, they can be management techniques or organizational changes that are innovative. Process innovations will improve the productivity of a company (increase the output using the same or fewer resource inputs), which results in benefits to the economy in various forms, including increased profits, wages, ownership distribution, employment and, in general, economic growth.

Technology aimed at the consumer market and that which may be aimed at other companies has to be managed and marketed differently. One major difference is that process innovations are generally accepted and diffused more quickly among users than are consumer products. They also tend to be smaller innovations (in terms of cost to purchase and/or use). Some are information-related and therefore not patentable, calling for different forms of protection of property rights and ownership. In short, the questions a technology transfer manager should ask and should evaluate for process-related technologies are quite different from those for which the expectations are that a final consumer product may emerge.

4. Demand-Related Attributes

Demand is a measure of the final use of the technology. The demand reflects who purchases the good or service, where it is purchased, how much of it is bought, and at what price. In the case of government mission-related technologies, the demand is measured by the extent of use--where, what agencies, and for what purposes.

Information about the present and future demand for a technology is extremely important for planning and marketing management. Because government managers tend to focus on their immediate goal--successful mission performance--the commercial end of marketing and sales estimation often is not an integral part of the government's technology development system. With the Congressional emphasis on facilitating the transfer of government-developed technologies to the private sector, the marketing and sales potential of a technology will become more visible and important to transfer agents as methods of determining commercial feasibility.

Demand-pull forces (market needs as the signal for technology development) require information not necessarily easily available to government managers. Nevertheless, this information will need to be generated, catalogued, and applied to the planning process. Without it, the results will be similar to the present situation--"supply push" will dominate government transfer efforts, which rarely are commercially successful. Early identification of market information including expected users, other applications, market trends, and sales estimates not only helps to establish the value of the technology, but often influences the direction of the research efforts, thus avoiding a technologically interesting, but non-marketable product.

By focusing on the uses of the technology (whether they are governmental or private), opportunities for cooperative research and development may become apparent. This information will indicate who else is conducting parallel development programs and could lead to joint projects which might in turn lead to new and exciting possibilities for better products and easier transfer and spin-offs. Such joint ventures could also reduce each participant's financial burden in the development process.

5. Financial (Past and Future)

This attribute overlaps other categories (see History, Science and Technology Underpinnings, Skill Requirements, and Risk); however, it is discussed separately because of its importance for portfolio management and strategic planning for technological development.

Under this category, the emphasis is on overall financial and accounting information. Examples include: sources and applications of funds committed to the technology, value of the resources used, current and projected budgets for the project, and expenditures of other participants. It should also include estimates and projections of income and profits (losses) from any ventures using or licensing the technology.

6. Cooperative Ventures (Past, Present, Possibilities)

Cooperative ventures represent a very good method of transferring technology, of getting research results that are greater than the "sum of their parts," and of conserving resources. The potential for such ventures is often revealed from sales and market data that would be collected for the classification process.

Arrangements between two or more laboratories, firms, government agencies, or even domestic and foreign governments are commonplace, and becoming even more so. They may be as simple as an exchange of personnel or data, or they may be extremely complex, involving all aspects of the technology process including the sales and marketing of final goods and services. However, in all arrangements, the resolution of basic issues is central to the agreements. Examples include: ownership and intellectual property rights of the technology, commitments of resources, and project management procedures. The terms of cooperative agreements should be included in the classification system.

7. Ownership/Legal Rights

No technology can be protected, sold, exchanged, or transferred in any way without some question of ownership and intellectual property rights being raised. In order to maximize returns on the investment and minimize potential legal problems (whether it is the government or a private company), ownership rights must be clearly established. Goals may be quite different for different organizations, even within the government. The technology's development history should be documented early in the process. A well-documented history that firmly establishes ownership will greatly facilitate transfer at a later stage.

8. Externalities

Externalities are the activities of one economic party that result in uncompensated benefits or costs to others. Externalities such as the environment, health, safety, education or other public/regulatory areas may be affected by technology development.

Assessing the full impact of new technologies is extremely difficult, and is often characterized by sizable measurement problems. However, an initial screening for externalities should be part of the classification process. A sensitivity to these issues and potential problems (negative externalities) that could lead to regulatory restrictions and affect sales is important early in the process, prior to committing significant resources to a technology.

9. Professional Skill Requirements (Needed to Complete and Exploit Development)

This attribute involves a thorough and detailed assessment of the human resources needed to complete the development of a particular technology. The most successful and speediest transfers of technology occur when individuals are able to move between organizations, take knowledge with them, apply that knowledge to new situations, interact with others, and instruct and train new people. Personnel management decisions and discussions with potential co-venturers or licensees will be facilitated by knowing personnel and time requirements needed to complete development and transfer.

10. Competition

Competition can take a number of forms and is a useful component in the classification system for descriptive and marketing purposes. An awareness of competitive forces enhances a technology's development and management. For example, competitive products or processes must be identified to estimate potential market share, which can be used as a basis to both evaluate a technology and to value it for transfer. Additionally, reviewing competitive products or processes will often illustrate a development change that needs to be made in order to "position" the end product in the market place. Another optional category for inclusion in the system is the intergovernmental competition for resources and personnel needed to initiate or continue technology development work.

11. National Security

In any government laboratory that deals with classified information and research on sensitive technologies, a description of the project and the requisite planning for future development absolutely requires an early assessment of national security classification issues. A sensitive technology may immediately be removed from further consideration for commercial transfer. Declassification procedures (if possible or desirable) may be initiated for parts of a classified project if commercial applications and potential warrant, and if national security would not be compromised.

12. Risk

During the very early stages of a project, the outcome of a research program or other technology-related project may be so completely unpredictable that no measure of the probability of success could be applied to the work. Uncertainty is the term applied to this situation.

Risk is the measure of the probable outcome of a project. As the project moves toward completion, the risk assessments associated with its outcome will change. Because degrees of risk are associated with financial flows through the opportunity costs of investment in alternative projects and the market rate of interest, information about the risk of a technology development project is essential for portfolio analysis and marketing management.

Two types of risk are applicable to technology development programs. The first is technological risk--that is, the measure of whether the technology does what it is expected to do. The second is market risk--the measure of the probability that the end product will be a profitable good or service. In addition, there may be an intermediate market for the technology--a bidder for a license or other arrangements to use the technology.

Often licenses are granted for more than one use. Risk analysis can be performed for each application and used as a method to value the technology for transfer.

13. Regulation

The government regulates for economic and public welfare reasons. Economic regulation occurs when there is the threat of monopoly power in the marketplace or when a good or service is considered so essential to the public that the government ensures (through price or allocation schemes) that it is available to all classes of consumers. Antitrust laws are enforced by the courts which generally rule on the cases that involve monopoly power. Regulatory commissions, such as the Federal Communications Commission (FCC) and the Interstate Commerce Commission (ICC), generally oversee public service types of regulation.

Health, safety and environmental regulations are another class of government involvement in the marketplace. The Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) are examples of regulatory bodies concerned with public health or safety.

Regulatory agencies can significantly affect the development and marketing of a product or process. For example, EPA's evaluation of pollution control equipment has a direct bearing on commercial viability of related innovative technology. The Food and Drug Administration (FDA) has a major role in determining the availability and timing of the introduction of new drugs to the market.

Therefore, regulatory requirements that affect all new technologies should be identified during the development stage. Planning for extensive testing to meet regulatory requirements must be included in the financial and marketing evaluations.

MAKING USE OF THE CLASSIFICATION SYSTEM

The attribute-based classification system for technology development just described, and detailed in Table VII-1, is an extensive list requiring a substantial data gathering and organizing effort. The matrix identifies attributes that are "essential" and those that are "optional." The expected and most likely use of each data element is also noted. Publications, computer data bases, and public relations programs oriented toward making the general public and specific users aware of a technology might utilize these data.

Some of the attributes that call for similar information can be compressed. Thus, each manager should feel free to develop priorities and modify the classification scheme to best accomplish agency or laboratory objectives. Another way of organizing the information would be a chronological sequence (i.e., beginning with past resources, disciplines involved, ownership, etc., moving to the present, and then to estimates of the future resource requirements and concluding with disposition of the technology).

In a government laboratory where there is a significant amount of defense or security-sensitive research conducted, the evaluation process may be very simple. Once the technology is determined to be sensitive, no further information may be needed related to technology transfer activities. However, gathering the data and keeping a file on that particular set of technologies is still useful for several reasons, including noting a declassification date or the possibility that further developments can be declassified for spin-off into the commercial sector.

For ease of use, any database developed for classifying technology should be entered into a personal computer so that it can be accessed

Table VII-1. Classification of Technology

Attribute	Essential or Optional	Description and Understanding of the Technology	Portfolio Management	Marketing Management
I. Science and Technology Underpinnings and Requirements (To Complete Development)				
Scientific Discipline(s)	Essential	X		X
Engineering Discipline(s)	Essential	X		X
Future S/E Requirements				
Laboratory	Optional	X	X	
Personnel	Optional	X	X	
Equipment	Optional	X	X	
Prototype	Optional	X	X	X
Test	Optional	X	X	X
Possible Interactions Between Disciplines	Optional	X		
II. History of the Technology				
Initial Impetus (Mission-related)	Essential	X		
Funds-Sources and Applications	Essential		X	
Locus of Actual Work: (What was done, when)				
Government	Optional	X		
Industry	Optional	X		
University/Not-for-Profit	Optional	X		
Domestic/Foreign	Optional	X		
Fully Documented Applications to Date	Essential	X	X	X
Significant Ownership/Property Rights to Date	Essential		X	X
III. Process of Innovation				
Present "Location" of Program (Where in Process of Innovation)	Essential	X	X	
Schedule for Completion of Remaining Elements	Essential	X	X	X
"Location" of Supportive/Complementary Technology	Optional	X		
IV. Demand-Related Attributes				
Sponsor's Intended Uses				
Mission-Related	Essential	X	X	X
Other Uses				
Government	Optional	X		X
Non-Government	Optional	X		X
Sponsor's Likely Uses				
Mission-Related	Optional	X		X
Other	Optional	X		X

Table VII-1 (Cont'd). Classification of Technology

Attribute	Essential or Optional	Description and Understanding of the Technology	Portfolio Management	Marketing Management
Other Government Entities	Optional	X		X
Private Sector Entities	Optional	X		X
Opportunities for Cooperative Development				
Between U.S. Government Entities	Optional	X	X	
Between U.S. and Other Government Entities	Optional	X	X	
Between U.S. Government and Private Entities	Optional	X	X	
Suggested Applications Beyond Sponsor's Mission-Related Uses	Optional	X	X	
V. Financial (Past, Present, Future)				
Source and Applications of Funds by:				
Date	Essential	X	X	X
Other Categories (e.g., discipline)	Optional	X	X	
Cash and In-Kind Resources	Essential	X	X	
Current Year Budgets	Essential	X	X	
Projections of Expected Income Where Applicable, e.g., Licenses	Optional		X	
VI. Cooperative (Past, Possibilities)				
Cooperative Arrangements				
Completed	Essential	X		
In Force	Essential	X	X	X
Prospective	Optional	X	X	X
Parties and Detailed Nature of Each Arrangement				
Resources (money, personnel) Commitments	Essential	X	X	X
Legal Arrangements				
Rights in Data	Essential	X	X	X
End Use Rights	Essential	X	X	X
VII. Ownership/Legal (Rights)				
Prior Constraints	Essential	X	X	X
Present Ownership/Rights to Technology	Essential	X	X	X
Ownership/Rights of Related Technologies	Optional		X	X
Publications/Documents that Affect Rights	Optional		X	X
Future Plans/Prospects for Legal Protection				X

Table VII-1 (Cont'd). Classification of Technology

	Attribute	Essential or Optional	Description and Understanding of the Technology	Portfolio Management	Marketing Management
VIII.	Externalities				
	Public/Social Externalities				
	Environmental, Health, Safety, Etc.	Optional	X	X	X
	Cost/Benefit Effects on Private Sector	Optional	X	X	X
	Economic Cost and Benefits				
	Public Sector	Optional	X	X	
	Private Sector	Optional	X		X
IX.	Professional Skill Requirements (Needed Complete and Exploit Development)				
	Science, Engineering	Optional	X	X	
	Marketing, Managerial, Entrepreneurial	Optional		X	X
	Financial	Optional		X	X
X.	Competition (Inter-Government and Other)				
	In Pursuit of Same/Similar Objective	Optional		X	X
	For Resources (Labs, Personnel, Etc.)	Optional		X	
XI.	National Security (e.g., Restrictions on Use/Transfer of Technology)				
	Requirements or Export Licenses-End Products	Essential	X		X
	Intermediate Restrictions				
	Publications	Essential	X		
	Speeches/Papers	Essential	X		
	Informal Discussions	Essential	X		
	Technical/Personnel Exchanges	Essential	X		
	Field/Specific Product Restriction	Essential	X		X
XII.	Risk				
	Nature of the Risk				
	Science Outcome Fails to Materialize	Optional	X		
	Technical Outcome Fails	Optional	X	X	
	Market				
	Technology Finds No Takers	Essential	X	X	X
	Product Doesn't Sell	Essential	X		X
	Financial				
	Who Bears the Risk?	Essential	X	X	
	Size of Risk (e.g., Dollars)	Essential	X	X	
	Relationships to Anticipated Rewards	Optional	X	X	

Table VII-1 (Cont'd). Classification of Technology

Attribute	Essential or Optional	Description and Understanding of the Technology	Portfolio Management	Marketing Management
XIII. Regulation				
Industry-Specific (e.g., chemical, drug, etc.)	Essential	X	X	X
Non-Industry Specific (e.g., antitrust)	Optional	X		X
International	Optional	X		X
Health/Safety	Optional	X	X	X

by any authorized person quickly, easily, and inexpensively. This will greatly enhance its operational use and will facilitate updating the information.

An example of the elements of a simple classification database for two sample products is given in Exhibit VII-1. Adaptations and additions can be made to the outlines as needed by the users.

A good classification system is one that is used. The key to encouraging maximum use of the system is simplicity. The system presented above is intentionally all encompassing, but note that it is not suggested or recommended that each laboratory attempt to develop technology classification databases that include all the listed attributes or all potential uses. Periodic review of the elements and the data should be required, and users of the system should be encouraged to suggest improvements for content and use.

SUMMARY

- A generalized set of attributes for classifying technologies has been developed.
- Each technology, organization, and user has a different purpose for accessing the information system; therefore, not all attributes will be used at once, nor will all of them have the same weight or importance to different programs and projects.
- Each laboratory should narrow or expand the list of attributes to carry out its particular mission and technology transfer responsibilities.
- Wherever possible, descriptions within each attribute should use existing classification systems, categories, and databases (e.g., SIC codes for industry groupings; academic disciplines for fields of science/engineering).
- The exercise of gathering and organizing the information may lead to new insights into the successful transfer of technology from government laboratories to the private sector.
- The classification system serves a support function. Gathering and organizing data must not become an end unto itself, generating information but not facilitating active transfer efforts.
- Finally, the information must be constantly kept up to date.

Exhibit VII-1. Examples of Simple Technology Classification Databases

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EXAMPLE: A process-related improvement developed in a government laboratory. (The example used is a NASA-developed product. The commercial potential was recognized early; however, problems in large scale manufacturing of the coating and quality control thwarted early attempts to commercialize the innovation. After at least one unsuccessful attempt at commercial-scale manufacturing, a company was able to overcome the technical problems and, under license from NASA, manufacture and sell the coating).

Technology: Modifications to a zinc dust anti-corrosion coating

Science and Technology Underpinning: Materials research, chemistry

History: Zinc coatings available; no easy and cost-effective way to apply them; government laboratory developed modifications that enabled the coating to be applied quickly and in one application. (Developed in conjunction with mission purposes.)

Demand: Government (federal, state, local)
Private (any structures subject to corrosion)

Property Rights: Process is patented by government, available for license

Skills Needed to Exploit Development: Large-scale production; avoid problems with clogging of applicators.

-continued-

Exhibit 1 (Cont'd). Examples of Simple Technology Classification Databases

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EXAMPLE: Satellite remote sensed images of earth - a major government mission-oriented program to develop new instruments and techniques. (This program involved numerous innovations and technological improvements. It was a multi-year, multi-million dollar program.)

Science and Technology Underpinnings: Physics, Optics, Measuring Instruments, Materials Sciences, Electronics

Future S/E Requirements: Numerous, as advanced techniques develop to enhance and improve imagery

History: Funding ($'s); first demonstration of use; government research

Prior Ownership Rights: Government patents; private research in photography and electronics.

Process of Innovation: In public and commercial use stage; however, markets not sufficiently developed to full commercial potential

Demand: Government primary users (list agencies/missions/functions)
Some private and foreign government demand (list)
Price sensitivity

Cooperative Programs: Very possible - high capital investments needed, foreign governments also investing in similar programs.

National Security: Overall, may be some sensitive issues; however, most technology involved is unclassified.

Risk: Market risk - high initial capital investment, easily reproduced products, regulations require non-proprietary availability of raw data, commercial markets not well developed, rapid advances in technology may radically change product and investment strategies.

<u>Issue Paper VIII</u>

EVALUATING TECHNOLOGY FOR TRANSFER

Issue Paper VIII

EVALUATING TECHNOLOGY FOR TRANSFER

Shackson Associates, Inc.

CONTEXT OF EVALUATION IN THE TRANSFER PROCESS

The context, role, and to some extent the process of evaluation depends on the type of institution in which the innovation process takes place. In a strongly market-oriented industrial development laboratory, for example, a set of market-oriented performance and cost criteria will typically be established a-priori, and the evaluation process will consist of simple comparisons with these criteria. On the other hand, a basic research laboratory may be the setting for an invention or for a discovery with technological implications. In addition, a market-oriented or mission-oriented laboratory may be the setting for an invention unrelated to market or mission, as, for example, when special equipment is developed to pursue a research project. In these latter cases, the context for evaluation is more uncertain, since we are dealing with "technology push" situations in which the implications of the discovery must be worked out and the invention must be looked at in terms of potential applications other than the one for which it was designed.

Evaluation is not a single event or step in the innovation process. It is rather a continuing series of interactions and analyses that begin with the first disclosure of invention or recognition of an application, and continue until a transfer strategy is formulated and implemented. Evaluation has several dimensions, each of which is separately discussed in a subsequent section:

- Documentation
- Identification of Potential Applications
- Determination of Development Status and Requirements
- Verification of Novelty and Significant Advantage
- Determination of Protection Status and Options
- Estimation of Value
- Development of a Transfer Strategy

The evaluation activity addresses the following questions:

- Is the technology described accurately and in sufficient detail for a potential buyer, licensee, or inventor to make an informed judgement regarding its commercial potential: Is the theory of its operation well explained, and have its characteristics been quantified?
- Has the technology been developed to the point that there is a well-defined product or service to sell? If not, what further development or packaging needs to be done, by whom, and at what time and dollar cost?
- Is the technology capable of being protected? If it has been publically disclosed, has a patent been obtained or applied for? If it has not been publically disclosed, can it be protected as a trade secret (i.e., can its function be described without disclosing how it performs this function)?
- Is the technology unique? If not, does it offer significant advantages over similar products already on the market?
- What is the value of the technology and to whom? Can products using it be sold at a price and in quantities sufficient to recover development, manufacturing and marketing costs with a satisfactory return?

The final question is of critical importance and is the most difficult to address in early stages. It is also the least understood by most research personnel, who consider the development complete upon demonstration of proof of principle. In fact, it is industry's experience that at the point of demonstration of an invention only about 10 percent of the ultimate investment will have been made.

It should be stressed again that evaluation is an iterative process. The above questions will be asked repeatedly during the innovation process, and the answers will change as innovation proceeds. The first iteration could be considered a Preliminary Value Screen, for the purpose of culling canditates with little or no potential.

Technology evaluation and assessment have been treated extensively in the literature. It is important to make a distinction between these two terms, which are frequently used interchangably. Evaluation examines technology from the perspective of its potential for commercial success. Assessment is concerned with the external impacts of the technology--both positive and negative--on society, generally from the perspective of a public policy maker. While the former considers externalities, they are viewed as costs and benefits to the commercial developer rather than as public policy issues.

The technology evaluation process may involve a number of participants in addition to the inventor(s) and the technology manager. Many managers have found that a panel of resource persons can play an important role in several steps of the evaluation process. Such a panel should be composed of respected individuals drawn from within the institution and from the outside technical and business community. Members are not expected to be experts in narrow scientific disciplines, but the panel should include members with broad technical understanding and commercial awareness. The following sections include several suggestions of specific ways in which such people may be employed. Specialized legal, technical, or commercial expertise may be obtained on a case-by-case basis as considered necessary by the manager.

Documentation and Tracking

Accurate, complete, timely, and well-structured documentation is essential to the success of a technology transfer activity. Proper documentation will:

- Identify the technology, capability, or other intellectual property as a transfer candidate.
- In the case of an invention: establish the data, circumstances, and the identity and preferences of the inventor(s).
- Provide a chronological record of activity related to the technology.
- Constitute the input to an inventory (database) of available technologies.
- Provide the primary input for the evaluation process.

Most research organizations have established policies regarding disclosure of inventions, and have implemented procedures for the protection of intellectual property. Few have expanded the documentation and tracking activity to include the additional functions listed above in support of the transfer process.

It is important to recognize that technology transfer is not limited to inventions. For example, the technology may be a process or may be embodied in a piece of equipment in regular use within a laboratory. In this case, the transfer is based on the recognition that this process or product is applicable to another function in a different setting. Or, the "technology" may be the specialized knowledge or experience of a staff member that can make a unique contribution in another setting. Since transfer strategies are dependent on the form of the technology (i.e., invention, process, application, or expertise), the documentation activity should accommodate the full range of transfer mechanisms and options.

The person who initiates the process is the inventor(s) in the case of an invention; or the one who recognizes the potential for transfer in the case of an existing process, product, or knowledge base. The initial document should require minimum information to encourage participation. As the evaluation process proceeds, more detailed information will be requested, and the inventor or submittor will continue to be the primary source of this information.

A variety of documentation forms and questionnaires now in use by government laboratories are designed primarily to assess the desirability and probability of obtaining patent protection. These forms can be broadened to include transfer candidates other than inventions, and can be complemented by additional documents that contribute to the evaluation.

At the outset, the inventor/submittor should provide the following information (when applicable):

- Security classification;
- Date of disclosure or submission;
- Name, title, address, telephone, citizenship of inventor(s) or submittor;
- Descriptive title of the invention or technology;
- Brief explanation of what the technology does;
- Statement of the development status of the technology; and
- A brief explanation of the potential for government use, commercial markets, and expected sales.

Additional information will be developed as the evaluation process proceeds.

IDENTIFICATION OF POTENTIAL APPLICATIONS

Evaluation must be performed in the context of the intended use of the technology, who will use it, who will produce and distribute it, and who will pay for it. In a simple case, an invention will occur as the inventor is seeking a solution to a specific problem (or is responding to a perceived opportunity), and the application will be obvious. Even in this case, it is important to attempt to identify other applications that may ultimately be of greater commercial significance than the original invention. In the more general case in which an invention occurs as a "by product" of basic or unrelated research, it is imperative that a structured process be undertaken to identify potential applications.

The inventor is the starting point in this process. Even if there is little familiarity with the commercial world, he (or she) will be best able to identify additional applications that could result by changing design parameters or operating conditions. The inventor is also well equipped to describe the invention in more than one way, suggesting alternative uses. It is important that the documentation system provide for and encourage this multiple response.

Several techniques are available to the technology manager for identifying potential applications:

- Contacting industry representatives in fields that appear to be relevant, with a non-proprietary description of the technology, and seek their views on potential applications.
- A third party who is familiar with the field may be retained.
- A meeting of persons selected from the resource panel may be convened. The group will typically consider several technologies. The meeting is conducted as a "brainstorming" session: that is, non-judgemental, open, and with quantity rather than quality as its objective. The inventor is then asked to comment upon the technical feasibility of applying the invention to the suggested applications. Any competing technologies known to the inventor or other parties should be identified as each application is considered.

However applications are identified, the process should be structured to yield not only statements about each of several potential applications, but also:

- The ultimate user group(s);
- The industry segment that could be expected to deliver a product based on this technology to the user group(s); and
- A short list of candidate firms for transfer within this industry segment.

As this process is repeated for many technologies, the laboratory will begin to accumulate information on the types of technologies that individual firms or industries are seeking. This knowledge can be supplemented by direct contact with the licensing executives of selected companies. Such information, if organized into a database, will become increasingly useful in subsequent evaluations.

STATUS

This phase of the evaluation process has two objectives: (1) to assess the stage of development of the technology; and (2) to estimate the costs and risks of the remaining steps of the innovation process. These steps are defined in many ways in the literature (see bibliography). In an industrial R&D organization, the process frequently begins with the identification of a problem or market need, followed by conceptual solutions. In a university or government laboratory, an invention often occurs as a result of basic research that is not directed at an identified commercial need. In this case, the process starts with the recognition that the technology (or other transfer candidate) has the potential for contributing to a commercial application. Each subsequent step (i.e., theoretical verification, reduction to practice, prototype, market testing, and production) is followed by a decision point, at which time the costs and risks of continuing are weighed against the expected benefits.

The further along this process, the more valuable the technology becomes and the more the chances for a successful transfer increase. It is unusual for a potential transferee to be interested until the principle of the technology has been demonstrated, but a prototype is not usually required.

The laboratory's documentation forms should be designed to incorporate these development steps and to track the technology step by step. The review panel has only to refer to the documentation and verify with the inventor in order to determine the status.

At later stages of the innovation process, the transferee will conduct cost/benefit assessments, but the originating laboratory should also perform these assessments as a part of the evaluation process. The inventor should outline his (her) perception of the events that must occur in order to move the technology to the next step, to estimate the manpower and materials, and to determine the probability for success. These costs and probabilities are then weighed against the probable value of the invention.

NOVELTY

Although the inventor may be convinced that the technology is unique, an evaluator must independently and systematically verify or refute this assertion. It is entirely possible to successfully transfer a technology that is not novel, but only if its competitors are known and the technology's advantages are understood. Novelty and/or comparative advantage assessments thus become critical evaluative functions.

As in other aspects of the evaluation process, the inventor is the first source of information. Frequently, disclosure and subsequent documentation will identify alternative ways of accomplishing the objectives of the invention and will explain its unique features and advantages. This information should be verified and updated in an interview and used as the basis for additional investigations. It is important to recognize that no method can establish novelty with absolute certainty. There is always the risk, for example, that another inventor will have conceived the same invention and filed a patent application. Until the patent issues, there is no way of establishing the conflict unless a public disclosure is made. There are, however, a number of ways of minimizing the risk.

A patent search will yield a good indication of novelty, and the probability of success in patenting the invention can be assessed. It will also help determine infringement risk--a concern of most potential transferees.

A careful review of manufacturers' literature, sales material, trade periodicals, and other literature in the appropriate fields provides independent input and will disclose unpatented technologies. Attendance at trade shows and conventions may provide insight into trends and developments that are not yet embodied in commercial products.

Assessment of novelty should also include consideration of the ease with which competitors can enter the market. Even a solid patent with well-written claims must be defended. If the technology is easily copied (e.g., its operation is obvious, and/or it requires little or no new manufacturing technology or know-how), it will be more vulnerable to competition than a technology for which the entry barriers are higher.

PROTECTION OPTIONS

A technology's "protectability" is an important aspect to consider in evaluating a technology. The legal concept of "intellectual property" and methods for protecting intellectual property are not discussed in this section. Protection is addressed only as it relates to the evaluation of a technology. The major point is that protection influences the perceived value of a technology and also affects the choice of transfer strategy. It should be stressed at the outset that a patent is not an essential ingredient to a successful transfer, and that the term "protection" should not be assumed to mean patent protection.

Government agencies usually have considered patents primarily in the context of protecting the government's right to use a technology. The concept of protection as a tool for transfer is of recent origin for them, accompanying a more general recognition that open publication does not offer a potential private-sector transferee the competitive advantage needed to introduce a new product.

There are, then, two considerations: (1) protecting the government's right to use the technology; and (2) establishing the most favorable protection environment for transfer. The former can usually be accomplished by filing a Statutory Invention Registration (SIR) without the time and expense associated with obtaining patent protection. The latter can be approached by patents or copyrights, or under certain conditions, by treatment of the intellectual property as a trade secret. This last approach is used frequently in industry-industry or university-industry transfers, but is thus far of limited application in the government-industry case.

At intervals during the evaluation process, the protection status should be documented, and the available options should be identified. This information will be used in developing the transfer strategy.

ESTIMATING VALUE

All of the previous steps in the evaluation process (i.e., identification of potential applications, development status, costs and risks, novelty, and protection options) are intended to establish the technology's market potential. It is at this stage that a transferee could be expected to be interested, if the technology is novel and can be protected during transfer. Each step in the evaluation procedure is a necessary condition for continuation of the innovation process, but none will ensure the interest of a potential buyer. The remaining step is to assess the worth or value of the technology to the transferee. It is the most difficult, the least precise, and is subject to change as the innovation process proceeds, but it is necessary in order to guide the transfer strategy and to provide a point of departure for negotiation.

Although there may be other important considerations (e.g., humanitarian or environmental benefits), the value of a technology is ultimately determined in the marketplace. Consequently, the valuation process is concerned with the ability of a recipient or buyer to earn a reasonable return on the investment that is necessary to take the technology to market. As in the prior evaluation steps, valuation builds on the documentation file. Although professional market research assistance is helpful, much of the process can be accomplished by the technology manager and a review panel, with input from respondents in industry who have a potential interest in the technology.

Several alternative approaches have been used by universities and government agencies:

- "Market-pull" analysis, when the original research was undertaken to address a perceived need. In this case, much of the valuation process precedes the work that led to the invention.
- Market test, when a technology is submitted to possible licensees to determine their interest. This can be a satisfactory approach only if there are several potential licensees, or if the laboratory management has done enough valuation to negotiate from a position of knowledge.
- Third-party expert (or expert system), when persons other than potential licensees are asked to perform the valuation. Certain computer-supported model approaches are available to assist in performing the valuation.
- Internal analysis, when the laboratory obtains industry data and performs its own valuation, possible with the assistance of computer models.

In the last two approaches, the valuation techniques vary in sophistication and cost, but all are essentially methods for organizing information for decision-making. The simplest, as practiced by some government agencies, is to ask the inventor for his (her) estimate of value. The most complex are computer-supported models that weigh many factors. The "right" technique will vary from case to case, depending upon the stage in the innovation process at which the valuation is being performed; the extent to which "market-pull" is a factor; the degree to which a commercial enterprise is already involved as a research sponsor, joint venture participant, or licensee; and the availability of "experts" with specialized commercial knowledge in the field of application.

Regardless of the techniques or the expertise used to perform the analysis, the valuation step must be done from the perspective of the potential transferee. Early identification of the industry segment (and even a set of companies) that are potential transferees is of utmost importance.

The simplest technique is essentially an industry analysis comprised of a checklist of questions and criteria that are likely to influence the ability of a firm to successfully commercialize the technology. Although this analysis is not strictly a valuation (i.e., it is not quantitative), it is a way of estimating potential interest. Typical questions or criteria address the following subjects:

- Competitive environment--what is the competition? What are the competitive advantages/disadvantages of the technology? What penetration could be expected?
- Nature of the market--size, growth rate, number and size of competitors, pace of technological change.
- Regulatory environment--existing regulations, required approvals, trends.
- Cost of entry--capital investment, marketing activities, compatability with existing facilities.
- Risks--product liability, obsolesence.
- Profitability--delivered cost, sustainable selling price, ability of competitors to retaliate, price elasticity.

Many of these questions will be difficult to answer, particularly in the early stages of innovation, but the primary advantage of the checklist technique (in addition to its simplicity) is to identify fatal flaws early in the process (e.g., a competitor with inherent advantages).

Scoring models, which may be computer-supported, are more sophisticated and costly. Staff or outside experts assign relative weights to each criterion/question, which is then answered, not by yes-no, but by a number (1-10) which represents the probability in the case of questions or estimated compliance with criteria. A weighted score is then obtained by multiplication. This technique can be criticized as arbitrary, but if care is used to maintain internal consistency, it can yield valuable insight. It is particularily useful in comparing alternative technologies in relation to a particular objective. Constraint analysis is a special use of this technique.

Next on the scale of complexity (and cost) are those techniques that attempt to quantify the profit potential of a project. These are applicable only to later stages of innovation when the necessary data are available. Profit potential analysis is invaribly undertaken by a potential transferee, and laboratory technology managers should also have this information available for negotiation purposes.

The simplest and least useful techniques estimate the point at which all costs of introducing a product will be recovered through sales revenues. Preference may be given to the project exhibiting the shortest payback period. This approach is obviously deficient in ignoring longer-term potential and in failing to differentiate between different income streams that produce the same cost-recovery period.

More useful approaches--using the same data--take into account the time value of money. One technique, the Internal Rate of Return (IRR) computes the return from an income stream as a percentage of the required investment. Typically a project proceeds if its IRR exceeds a "hurdle rate" established by the firm, based on returns expected from alternative uses of capital. A second technique--Net Present Value (NPV)--calculates the discounted present value of all expense streams. In this case, a discount rate is chosen to reflect the cost of capital to the firm. Many accounting computer programs offer these techniques and are often a minimal and worthwhile investment.

All of these techniques are straightforward once the data are known. The data become more readily available and more accurate as the innovation process proceeds. Therefore, the simpler techniques are generally used early, with the more complex techniques reserved until later in the innovation process. The objective, at each stage, is to give the laboratory an indication of the value of the technology to a transferee. At early stages the answer may be simply "attractive or not attractive." At later stages, it should (as a minimum) estimate order of magnitude, ROI, or NPV. Rough numbers are better than none, and are also useful in eliciting similar information from the potential transferee.

DEVELOPMENT OF A TRANSFER STRATEGY

Evaluation is not an end in itself. Its purpose is to contribute to the process of managing technology transfer. If a technology clearly fails to meet one or more of the established criteria, the evaluation process may yield a recommendation not to proceed. If, on the other hand, all criteria are satisfied, the evaluation process should provide more than a simple "proceed" recommendation. The transfer strategy is a "roadmap" for moving the technology from its present state to commercialization. The strategy takes into consideration the stage of development, protection options, potential applications and users, and the estimated value of the technology. It is reviewed and revised occasionally as the innovation process proceeds, but its milestones and decision points will serve to keep the process on track.

There may be several different strategies for a single technology, each in support of a different application. The end points span a wide range of options which include:

- Drop - do no further work.
- Publish - but do not attempt further activity.
- Protect government interest with SIR - but do nothing further.
- Establish joint development program with private sector firm.
- Exchange scientific personnel.
- Publish - and license subsequent knowhow.
- License or sell as trade secret.
- Patent - and license rights under patent.

These activities may involve large or small established firms--both foreign and domestic, startup firms, individuals, or a consortium of several organizations. There is no single decision tree that will lead to the "right" strategy. The process typically involves the following types of decisions:

- If the applications analysis fails to find an existing firm whose capabilities and market strengths match the technology, it may be best to work with a startup. On the other hand, if there are substantial entry barriers (e.g., expensive production capacity or a well-established marketing organization) it may be well to work with an established firm with these characteristics.

- If the status assessment indicates substantial additional costs and risks prior to commercialization, a large firm may be indicated. If the technology is well along toward commercialization and minimum additional costs are anticipated, a small firm or startup may be the choice.
- If the novelty assessment suggests that large expenditures may be required for patent defense, or that a preemptive marketing strategy will be necessary to secure market penetration, a firm with appropriate resources should be selected.
- If a technology is to be transferred as a trade secret, established firms may tend to be more concerned about possible infringement suits than would a small company.

Considering these and similar questions, the technology manager should define the strategy's appropriate endpoint and identify the actions that should be taken to achieve that end.

BIBLIOGRAPHY

POLICY

The three major U.S. innovation policy reports are:

1. U.S. Department of Commerce, Technological Innovation: Its Environment and Management. Although published in 1967, it still contains unique insights.

2. U.S. Department of Commerce, Domestic Policy Review of Industrial Innovation. Published in 1979, this was the Carter Administration's contribution to an understanding of technology policy.

3. President's Commission on Industrial Competitiveness, Global Competition: The New Reality. Published in 1985, this report forcefully presents the current emphasis on U.S. industrial competitiveness.

Albert H. Teich and Jill Pace, Science and Technology in the USA is a useful compendium of information sources and provides extensive coverage of Federal agencies. Although journalistic in approach, Deborah Shapley and Rustum Roy's Lost at the Frontier: U.S. Science and Technology Policy Adrift contains a good discussion on the impact of Vannevar Bush's 1945 publication, Science the Endless Frontier, which has inadvertently made it difficult for the United States to formulate an aggressive technology policy. Ralph Landau and Nathan Rosenberg, eds., The Positive Sum Strategy contains a number of insightful articles and, in particular, an entire section on the policy framework for technological change. Of the older literature, Richard Nelson's Technology, Economic Growth and Public Policy can still be read with benefit.

Useful articles on innovation and technology policy include:

1. John N. Logsdon, "Federal Policies Towards Civilian Research and Development: A Historical Overview," pages 9-26 in Denis O. Gray et al., eds., Technological Innovation.

2. Trudy Solomon and Louis Tornatzky, "Rethinking the Federal Government's Role in Technological Innovation," pages 41-53 in Denis O. Gray et al., Technological Innovation.

3. Roy Rothwell, "Technological Change and Reindustrialization: In Search of a Policy Framework," pages 97-122 in Jerry Dermer, ed., Competitiveness Through Technology.

Unfortunately, none of these works contains a good historic overview of technology transfer policy in the context of U.S. innovation policy. The best effort in this direction, though it concentrates on international technology transfer, is Sherman Gee, Technology Transfer, Innovation, and International Competitiveness. For an earlier, but still useful, approach, the reader may wish to refer to Albert Shapero, "Towards a National Technology Transfer Program" (Working Paper 72-57, Bureau of Business Research, The University of Texas at Austin).

TECHNOLOGY

Although there are many works dealing with the social impact of technology, there are no books in English dealing with the formal qualities of technology. This is because the term is relatively new, it attempts to encompass too many disparate phenomena (other languages such as German have various terms for the components of "technology"), and the major theoretical struggle has been to establish technology as a separate area of study by distinguishing it from science. Persons wishing to follow these emergent problems should refer to the various issues of *Technology and Change*. A good overview of the issues is contained in John M. Staudenmaier, *Technology's Storytellers*, which is a history of *Technology and Change*.

The two persons who have done most to establish technology as a separate discipline of study are Nathan Rosenberg (particularly his *Inside the Black Box*) and Devendra Sahal (particularly his *Patterns of Technological Innovation*). The latter work introduces the concept of technology as function, but focuses on the development of technologies over time rather than on the formal aspects of technology. The reader may also wish to refer to Joseph Agassi, *Technology: Philosophical and Social Aspects* and to three articles by Michael Fores that attempt to characterize technology by distinguishing it from science: (1) "What is Technology" (*New Scientist*, June 15, 1972, pages 617-618); (2) "Science v. Engineering" (*New Scientist*, January 8, 1970, pages 58-59); and (3) "Technik: The Relevance of a Missing Concept" (*Nature*, September 1977, page 2).

A good overview of the historic development of the term is found in Stephen V. Monsma *et al.*, *Responsible Technology*. Studies on the distinguishing features of technology have concentrated on the knowledge component. The best works in this regard are Rachael Laudan, *The Nature of Technological Knowledge* and various articles by Edwin T. Layton, including: (1) "Mirror-Image Twins: The Communities of Science and Technology in 19th-Century America" (*Technology and Culture*, vol. 12, pages 562-580); (2) "Technology as Knowledge" (*Technology and Culture*, vol. 15, pages 31-41); and (3) "American Ideologies of Science and Engineering" (*Technology and Culture*, vol. 17, pages 688-701). A strong case for technology as activity is made in Peter Drucker, *Technology, Management and Society*.

The nature of technology and of technological knowledge is best seen through case studies. The best works in this area are Edward W. Constant, *The Origins of the Turbojet Revolution*; Nathan Rosenberg and Walter Vincenti, *The Britannia Bridge*; and three articles by Walter Vincenti in *Technology and Culture*: (1) "The Air Propeller Tests of W. F. Durand and E. P. Leslie: A Case Study in Technological Methodology" (vol. 20, pages 712-751); (2) "Control Volume Analysis: A Difference in Thinking Between Engineering and Physics" (vol. 23, pages 145-174); and (3) "Technological Knowledge Without Science: The Innovation of Flush Riveting in American Airplanes, ca. 1930-ca. 1950" (vol. 25, pages 540-576).

Many of the previously mentioned studies deal with the differences and relationships between science and technology. Readers wishing to pursue this theme should also consult Derek Price's "Is Technology Historically Independent of Science" (Technology and Culture, vol. 4, pages 553-568); "Notes Towards a Philosophy of the Science/Technology Interaction" (pages 105-114 in Rachael Laudan, ed., The Nature of Technological Knowledge); "Of Ceiling Wax and String" (Natural History, No. 1, 1984, pages 49-56); and "The Science/Technology Relationship, the Craft of Experimental Science, and Policy for the Improvement of High Technology Innovation" (pages 225-258 in National Science Foundation, The Role of Basic Research in Science and Technology). See also J. Langrish's "Does Industry Need Science" (Science Journal, December 1969, pages 81-84); and "The Changing Relationships Between Science and Technology" (Nature, vol. 250, pages 614-616).

TECHNOLOGY TRANSFER

The two major organizations concerned with Federal technology transfer are the Federal Laboratory Consortium for Technology Transfer and the Technology Transfer Society. The best way to keep abreast of current developments in technology transfer is through reference to the newsletters of both organizations and attendance at their annual meetings. Both organizations publish the papers of their annual meetings, and the Technology Transfer Society publishes two issues each year of The Journal of Technology Transfer.

Excellent bibliographies on technology transfer are published intermittently by NTIS under the title Technology Transfer: General and Theoretical Studies. The student of technology transfer should also consult J. W. Creighton et al., Technology Transfer: Concepts With Supporting Abstracts for recommended readings with respect to technology transfer issues, concepts, and mechanisms.

A good encyclopedic overview of technology transfer is contained in Samuel I. Doctors and Charles Stubbart, "Technology Transfer," pages 310-343 in Jack Belzer et al., eds., Encyclopedia of Computer Science and Technology, volume 15, supplement.

The best theoretical work on technology transfer remains Frank Bradbury et al., eds., Transfer Processes In Technical Change, which was published in 1978. In addition, the reader should consult Louis N. Mongavero and Robert S. Shane, What Every Engineer Should Know About Technology Transfer and Innovation (particularly chapters 1-5 and 7-8) and William H. Gruber and Donald G. Marquis, eds., Factors in the Transfer of Technology, which concentrates on technology transfer through the movement of personnel.

The aforementioned books deal with all aspects of technology transfer, including such things as intra-firm and international transfer. There is no comprehensive work on technology transfer from Federal laboratories. The closest approach to an overview is contained in Steve Ballard et al. (of the Oklahoma University Science and Public Policy Program), Improving the Transfer and Use of Scientific and Technical Information (in three volumes prepared for the National Science Foundation).

The journal literature on technology transfer is, of course, voluminous. Two articles that are decisive for a proper theoretical position on technology transfer from Federal laboratories are:

1. Albert H. Teich and W. Henry Lambright, "Federal Laboratories and Technology Transfer: An Interorganizational Perspective," pages 425-438 in Donald E. Cunningham et al., eds., Technological Innovation: The Experimental R&D Incentives Program. Although this is an old article, it sets the right accent.

2. Martin D. Robbins, "Technology Transfer as a Process: Lessons From the Past," pages 65-72 in A Synthesis of Technology Transfer Methodologies, U.S. Department of Energy, 1984.

The technology transfer literature suffers from a paucity of fully documented case studies. In order to gain a feel for technology transfer as a process, it is necessary to cover the mechanics of how things were done rather than simply what was done. Useful examples may be found in Denver Research Institute, The Commercial Application of Missile/Space Technology (prepared for NASA in 1963); Syracuse University Research Corporation, Federal Laboratories and Technology Transfer: Institutions, Linkages, and Processes (prepared for NSF in 1974); and National Research Council, Committee on Computer-Aided Manufacturing, Innovation and Transfer of U.S. Air Force Manufacturing Technology: Three Case Studies (prepared for Air Force Systems Command in 1982). However, the only publications that give a feel for the complexities of transfer use university examples. The best of these is Richard S. Goldhor and Robert T. Lund, University-Industry Technology Transfer: A Case Study In Advanced Technology (Center for Policy Alternatives, Massachusetts Institute of Technology, 1981). Good university case studies (particularly the reach toothbrush example) can also be found in Harvey D. Jones, Jr., The Commercialization of New Technologies: Transfer From Laboratory to Firm (Sloan School of Management, Massachusetts Institute of Technology, 1983).

Lastly, the reader may wish to refer to Arthur Cordell and James Gilmour, The Role and Function of Government Laboratories and the Transfer of Technology to the Manufacturing Sector (Science Council of Canada, 1976). Although this work deals with the Canadian experience, it is the most comprehensive and detailed study of transfer from government labs to the private sector and contains many U.S. parallels.

ACTORS AND MECHANISMS

There is no handbook describing actors or mechanisms in the technology transfer process, although there are numerous articles dealing with specific actors and mechanisms. The best way to keep abreast of new insights is to maintain a network of peers, read the Journal of Technology Transfer, and attend or read the proceedings of the Federal Laboratory Consortium and the Technology Transfer Society.

For a basic description of the technology transfer activities of all Federal agencies, two reports by the Denver Research Institute produced under the direction of Richard L. Chapman should be consulted: (1) The Uncounted Benefits: Federal Efforts in Domestic Technology Transfer (covering all agencies with the exception of NASA); and (2) NASA Partnership with Industry: Enhancing Technology Transfer. The DRI reports provide an overview. For a more detailed analysis of activities with supporting survey data, the FLC's Interagency Study of Federal Laboratory Technology Transfer Organization and Operation should be consulted. In addition, every other year the Center for the Utilization of Federal Technology at NTIS compiles a comprehensive report on the transfer activities of all Federal agencies that fall under the jurisdiction of the Stevenson-Wydler Act.

One of the primary actors in transfer processes is, of course, the Federal laboratory system itself. Thus, in order to understand the problems and opportunities of transfer and applicable mechanisms, it is necessary to understand the Federal laboratory culture. The best introduction to laboratory culture (with contrasts and parallels to the university system) remains Alvin Weinberg's early book Reflections on Big Science. Weinberg was for many years director of Oak Ridge National Laboratory. See also his "Government, Education, and Civilian Technology" (in Aaron W. Warner et al., eds., The Impact of Science on Technology).

The best theoretical background for actors and mechanisms can be obtained from Frank Bradbury et al., eds., Transfer Processes in Technical Change (particularly the chapter on mechanisms). This book deals with technology transfer in general and not specifically with Federal laboratory transfer. The best brief introductions to Federal laboratory transfer actors and mechanisms are Eugene Stark, "Federal Laboratories: Technology Resources and Transfer Champions" (in American Chemical Society, Leaping the Technology Transfer Barriers) and Joseph Morone and Richard Ivins, "Problems and Opportunities in Technology Transfer from National Laboratories to Industry" (Research Management, May 1982, pages 35-44).

There are a number of articles and reports dealing with specific transfer actors and mechanisms (many of which are concerned with intra-firm and inter-firm transfer problems). Examples include Roger L. Whiteley and Herman Postma, "How National Laboratories Can Supplement Industry's In-House R&D Facilities" (Research Management, November 1982, pages 31-42); Richard L. Chapman (Denver Research

Institute), NASA's New Technology Reporting System; and Arthur P. Lien, "Acquiring and Selling Technology: The Role of the Middleman" (Research Management, May 1979, pages 29-31).

In addition, there are reports and articles dealing with general transfer mechanisms such as information dissemination. Examples include Tora K. Bikson et al., Scientific and Technical Information Transfer: Issues and Options (prepared for NSF); and Margery H. King, Improving Industrial Access to NBS (prepared for the Commercial Development Association).

Each actor and mechanism must be approached in a systematic fashion for study purposes, since good, comprehensive works are not available, and parallels must be drawn from private sector experience. For example, in the general area of "champions," it would be necessary to consult Alok K. Chakrabarti, "The Role of Champion in Product Innovation" (California Management Review, Winter 1974, pages 58-62); Modesto A. Madique, "Entrepreneurs, Champions, and Technological Innovation" (in Michael L. Tushman and William L. Moore, eds., Readings in the Management of Innovation); and Paul Jervis, "Innovation and Technology Transfer--The Roles and Characteristics of Individuals" (IEE Transactions on Engineering Management, February 1975, pages 19-27). It would then be necessary to relate these insights to Federal laboratory problems by consulting such things as Bernadine A. Lennon, Technology Transfer Agents' Perceptions of the Technology Transfer Process (prepared at the Naval Postgraduate School).

Some practical advice can be obtained form three handbooks by Hyman Olken: (1) The Technical Communicator's Handbook of Technology Transfer; (2) Technology Transfer: How to Make It Work; and (3) The High Tech Industry Manual (all from Olken Publications, Livermore, California). The last two of these deal with how industry should seek lab technologies.

In addition, a close eye should be kept on publications emanating from Oak Ridge National Laboratory. Recent examples include E. J. Soderstrom, "New Initiatives in Technology Transfer" (in Utah Innovation Foundation, First International Technical Innovation and Entrepreneurship Symposium); E. J. Soderstrom et al., Enhancing Technology Transfer Through Laboratory/Industry Cooperative Research; and William W. Carpenter, "Statement" (in Technology Transfer and Patent Policy: DOE and Other Perspectives, U.S. House of Representatives, Committee on Science and Technology, July 15, 1985).

Lastly, references on particular mechanisms such as cooperative research can be found in other parts of this bibliography.

TECHNOLOGICAL INNOVATION

A recent comprehensive bibliography on technological innovation is available in the National Science Foundation's Technological Innovation: Reviewing the Literature (prepared by Louis G. Tornatzky et al.). However, the document itself concentrates heavily on the adoption of innovations in an organizational context. An older work, Technological Innovation: A Critical Review of Current Knowledge (edited by Patrick Kelly and Melvin Kranzberg) also contains an excellent bibliography and covers the full range of innovation processes.

The best general introduction to technological innovation in the private sector is Donald A. Schon, Technology and Change. Good, brief introductions include: (1) Donald G. Marquis, "The Anatomy of Successful Innovations" (in Michael L. Tushman and William L. Moore, eds., Readings in the Management of Technological Innovation; (2) Martin O. Robbins et al., "The Technological Innovation Process in the Private Sector" (in Donald E. Cunningham et al., eds., Technological Innovation: The Experimental R&D Incentives Program); (3) James A. Bright, "The Process of Technological Innovation--An Aid to Understanding Technological Forecasting" (in James R. Bright and Milton E. Schoeman, eds., A Guide to Technological Forecasting); and James M. Utterback and William J. Abernathy, "A Dynamic Model of Process and Product Innovation" (Omega, 1975, pages 639-656).

Besides the Schon book, excellent expressions of factors that must be taken into consideration by private sector innovators are: (1) Stephen J. Kline and Nathan Rosenberg, "An Overview of Innovation" (in Ralph Landau and Nathan Rosenberg, eds., The Positive Sum Strategy); (2) Peter Drucker, Technology, Management and Society, Chapter 9, "Business Objectives and Survival Needs;" (3) James M. Utterback, "Innovation and Industrial Evolution in Manufacturing Industries (in Bruce R. Guile and Harvey Brooks, eds., Technology and Global Industry); and (4) David J. Teece, "Capturing Value from Technological Innovation" (in Bruce R. Guile and Harvey Brooks, eds., Technology and Global Industry).

R&D is becoming much more integrated into overall company objectives and activities. On this changed perspective, see Rowland W. Schmitt, "R&D in a Competitive Era" (Research Management, February 1987, pages 15-19). Good examples of current industry practice are contained in H. W. Coover, "Programmed Innovation--Strategy for Success" (in Ralph Landau and Nathan Rosenberg, eds., The Positive Sum Strategy) and in Donald N. Frey, "Managing for Innovation" (in Argonne National Laboratory Technology Transfer Center, Industry, Innovation, and Technology Transfer). The new perspective is modeled in Stephen J. Kline, Research, Invention, Innovation, and Production: Models and Reality (Stanford University Department of Mechanical Engineering).

The incremental nature of technological development is emphasized in Devendra Sahal, Patterns of Technological Innovation and in

William J. Abernathy and James M. Utterback, "Patterns of Industrial Innovation" (Technology Review, June/July 1978, pages 41-47).

Unfortunately, there are no case studies describing the entire process from invention through market introduction of a product. Tracy Kidder, in The Soul of a New Machine, and P. Ranganath Nayak and John M. Ketteringham, in Breakthroughs, provide exciting accounts of examples at the invention end of the spectrum. Design, which is a central factor in innovation, is illustrated in Richard C. Bourne, "Development of a Circular Strike Plate" (in H. O. Fuchs and R. F. Steidel, eds., 10 Cases in Engineering Design) and in David L. Marples, "The Decisions of Engineering Design" (IRE Transactions on Engineering Management, June 1961, pages 55-71).

Lastly, for a sense of how innovation produces a dynamic economy, Joseph Schumpeter's The Theory of Economic Development is indispensable. New insights into innovation processes are being provided by economists operating in the Schumpeterian tradition. Of particular note is An Evolutionary Theory of Economic Development by Richard R. Nelson and Sidney G. Winter.

TECHNOLOGY MANAGEMENT

Books and articles on technology management in the private sector generally concentrate on the management of R&D and on the correlation of R&D activities with other company functions. As a consequence, the management of technology transfer in the private sector is often couched in terms of the movement of a technology from one company function to another.

An excellent example of this approach to technology management is Michael J. C. Martin, *Managing Technological Innovation and Entrepreneurship*, which also covers problems of technology transfer within the company. There are, of course, numerous studies that deal with particular aspects of technology management. Of particular interest are Edward B. Roberts, "Strategies for Improving Research Utilization" (*Technology Review*, March/April 1972, pages 33-39) and Robert A. Burgleman and Leonard R. Sayles, *Inside Corporate Innovation*, which deals with internal corporate venturing. The reader should also consult various articles in Michael L. Tushman and William L. Moore, eds., *Readings in the Management of Innovation*.

Technologies in the private sector can be looked at as assets with potential uses other than in product development. This expands the scope of technology management to include transfer of technologies outside the organization (e.g., through licensing). The best book on this subject is C. G. Ryan, *The Marketing of Technology*. Also of interest are Edward B. Roberts' "Is Licensing an Effective Alternative" (*Research Management*, September 1982, pages 20-24) and "New Ventures for Corporate Growth" (*Harvard Business Review*, July-August 1980, pages 134-142).

Unfortunately, the theme of technology management in this comprehensive sense has not yet become topical (note that Ryan's book stresses marketing, rather than managing, technology). Part of the reason is that the private sector experience with respect to using technologies other than for product development has not been good. With a few notable exceptions, for example, returns from licensing have not been sufficient to justify the activity. Although it is beneficial to review the private sector experience, Federal laboratories should keep in mind that they are not hemmed in by profit considerations.

Although there are many articles and reports covering particular areas of management in Federal laboratories, there do not appear to be any works covering comprehensive technology management or the management of technology transfer in the Federal laboratories when secondary applications are the objective. Some useful recommendations can be gleaned from three works that deal with the management of transfer activities that are directed toward commercialization of primary mission R&D: (1) Peter W. House and David W. Jones, *Getting It Off the Shelf: A Methodology for Implementing Federal Research*; (2) Norman B. McEachron *et al.*, *Management of Federal R&D for Commercialization*; and

(3) Daniel J. Entingh *et al.*, *Guidebook for Technology Transfer Managers: Moving Public R&D to the Marketplace.*

The U.S. Department of Commerce is beginning to look at comprehensive technology management and the management of technology transfer in Federal laboratories. The first fruits of this effort are Thornton J. (Tip) Parker, "Proposed System for Managing Technology in Federal Laboratories" (unpublished).

COOPERATIVE RESEARCH AND CONFLICT ISSUES

The National Science Board's *University-Industry Research Relationships: Selected Studies* (published by the National Science Foundation in 1983) contains an excellent annotated bibliography on cooperative research. Bernard D. Reams has also prepared an extensive bibliography that appears in his *University-Industry Research Partnerships*. The major periodicals and journals that frequently contain articles on the subject include *Science*, *Research Management*, *Les Nouvelles*, and the *Journal of the Society of Research Administrators*.

Very little work has been done on cooperative arrangements with Federal laboratories. E. J. Soderstrom *et al*. have contributed an excellent description of activities at Oak Ridge National Laboratory in *Enhancing Technology Transfer Through Laboratory/Industry Cooperative Research and Development*. The Center for Science and Technology Policy at New York University has conducted a survey of Federal laboratory activities as part of a larger study entitled *Collective Industrial Research*. Volume I of this work presents survey results of participants in university-industrial cooperative arrangements and summarizes the results of the Federal laboratory survey. Details of the Federal laboratory survey will be available in the forthcoming Volume II.

The Center for Science and Technology Policy also conducted surveys of a broad range of university-industrial interactions, including cooperative research. The results are summarized in the Fourteenth Annual Report of the National Science Board (1982), which is entitled *University-Industry Research Relationships: Myths, Realities, and Potentials*. The detailed survey results are very useful and are available in separate volumes.

The conflict issues involved in strengthening research ties between universities and industrial firms have focused primarily on maintaining the institutional integrity of the universities. Good discussions of the issues appear in *Industry and the Universities: Developing Cooperative Research Relationships in the National Interest*, which was published by the National Commission on Research in 1980, and in Thomas W. Langfitt, ed., *Partners in the Research Enterprise*.

Derek Bok in "President's Report: Business and the Academy" (*Harvard Magazine*, May/June 1981, pages 23-35) and William J. Broad in "Pajaro Dunes: The Search for Consensus" (*Science*, vol. 216, April 9, 1982, page 155) also provide good coverage of the issues, primarily from the university's perspective. Bernard D. Reams addresses the major legal issues in structuring R&D agreements in *University-Industry Research Partnerships*.

Industry, Innovation, and Technology Transfer: Lectures Delivered at the Directors Special Colloquium, published by the Argonne National Laboratory, is an excellent overview of the industrial perspective.

See particularly Roland W. Schmitt's "Technology Transfer--Lessons from Industry" (pages 33-55). K. W. McHenry provides an excellent discussion of the role of R&D within a firm and its relationship to R&D derived from external sources in "University-Industry Research Cooperation: An Industrial View" (SRA Journal, Fall 1985, pages 31-43). A good case study of university interactions with a company is contained in W. G. Simeral, "The Evolution of Research and Development Policy in a Corporation: A Case Study" (in Thomas W. Langfitt, ed., Partners in the Research Enterprise).

The National Science Foundation has a series of publications related to the establishment, operation, and evaluation of NSF-funded cooperative research centers at universities. Of particular interest are Louis G. Tornatzky et al., University-Industry Cooperative Research Centers: A Practice Manual (1982) and Denis O. Gray and Teresa Gidley, Evaluation of the NSF University/Industry Cooperative Research Centers: Descriptive and Correlative Findings From the 1983 Structure/Outcome Surveys (1986). See also Denis O. Gray et al., "NSF's Industry-University Cooperative Research Centers Program and the Innovation Process: Evaluation-Based Lessons" in Denis O. Gray et al., eds., Technological Innovation.

Sample research agreements and forms are included in Preston W. Grounds, University-Industry Interaction: Guide to Developing Fundamental Research Agreements (published in 1983 by the Council for Chemical Research).

TRANSFER PREPARATION

The initial phases of a technology transfer program involve creating an innovative environment, stimulating invention awareness, and encouraging people to come forward with ideas. Literature relevant to such efforts includes Tudor Rickards, Stimulating Innovation; Willard Marcy (of the Research Corporation), Stimulating Invention Disclosures by Faculty Researchers (prepared for NSF); Bruce Merrifield, "Stimulating Technological Innovation--Nurturing the Innovator" (Research Management, November 1979, pages 12-14); George E. Manners et al., "Motivating Your R&D Staff" (Research Management, September/October 1983, pages 12-16); and Joseph Gartner and Charles S. Naiman, "Making Technology Transfer Happen" (Research Management, May 1978, pages 34-38).

With respect to classifying, evaluating, and managing technologies for transfer, the best works are:

1. Frank J. Contractor, International Technology Licensing. This book investigates the nature and composition of technology transfers while also analyzing the costs incurred and revenues received in both international industry and developing nations. Factors influencing the compensation that technology licensor firms receive and the bargaining power of the parties are also addressed.

2. Robert G. Cooper, "New Product Performance and Product Innovation Strategies" (Research Management, May/June, 1986, pages 17-25). This article presents the results of a study testing the hypothesis "the new product strategy a firm elects decides the performance of the company's new product program." Such variables as market, the type of product, and the nature of the firm (along with level of commitment) are investigated and discussed. The conclusion is that when trying to gauge potential success, evaluation of the innovation strategy chosen by the firm is as important as evaluation of the product.

3. D. Bruce Merrifield, Strategic Analysis, Selection, and Management of R&D Projects. This AMA "Management Briefing" monograph describes an R&D management system based on constraint analysis that allows dissimilar opportunities to be compared.

4. D. Bruce Merrifield and Robert L. Bovey, Evaluating R&D and New Product Development Ventures. This report, prepared jointly by Coopers & Lybrand and the Office of Productivity, Technology and Innovation of the U.S. Department of Commerce, is a summary of techniques used for evaluating technologies for commercialization.

5. Ithiel de Sola Pool, Forecasting the Telephone: A Retrospective Technology Assessment. The thesis of this book is that in successful technology assessment, market and technical analysis must be brought to bear simultaneously. Alone, both of them fail; yet together, they can produce some very prescient forecasts. Using the telephone as a case study in retrospect, such issues as resource use, environmental impact, development of related technology, social impact, and economic consequences are discussed as valid considerations in the evaluation of the telephone as a "new," potentially successful product.

6. J. P. Reinhardt, "Identifying Technologies to License" (Les Nouvelles, March 1984, pages 7-11). This article discusses development and commercialization of new products and processes in South Africa. The author points out the importance of identifying key products and technologies through means of a systemized procedure.

7. Gerald Udell, et al., Guide to Invention and Innovation Evaluation (University of Oregon, College of Business Administration). This monograph describes the evaluation system developed at the Oregon Innovation Center. This computer-supported, systematic analysis employs a questionnaire that is intended to be completed by the inventor and by several evaluators who are not necessarily skilled in the area of the invention. A proprietary weighing and analysis system provides preliminary indications of risk, cost (time, money, and effort), payroll, and commercialization strategies.

PATENTING AND MARKETING

The best brief introduction to patent matters is the U.S. Department of Commerce's *General Information Concerning Patents*. Also of interest are Earl W. Kintner and Jack Lahr, *An Intellectual Property Law Primer*; Bernard Rivkin, *Patenting and Marketing Your Invention*, which concentrates on patenting; Marcus B. Finnegan and Alfred A. D'Andrea, "The Black Box Problem: Using Pre-Negotiation Secrecy Agreements to Govern Disclosure of Technology to Potential Licencees" (*The Journal of Corporation Law*, Summer 1978, pages 507-531); and National Council of University Patent Administrators, *Intellectual Property Series*. Good, brief articles on patenting are Douglas B. Henderson, "Role of Patents, Trade Secrets and Know-How in the Transfer of Technology" (*Technology Transfer Society Symposium 1981*, pages 1.4-1 through 1.4-3); and Joseph S. Iandiorio, "Technology Transfer: What and From Whom" (*1980 IEE Engineering Management Conference Record*, pages 116-120).

The best comprehensive work on technology marketing is C. G. Ryan's *The Marketing of Technology*. Also of interest is Thomas M. Jacobius and Robert S. Levi, "The Role of Marketing in Technology Transfer" (*Technology Transfer Society Symposium 1980*, pages 12-1 through 12-11) and David Ford and Chris Ryan, "Taking Technology to Market" (*Harvard Business Review*, March-April 1981, pages 117-126).

With respect to licensing, parallels with private sector experience can be drawn from Edward B. Roberts, "Is Licensing an Effective Alternative" (*Research Management*, September 1982, pages 20-24); David McDonald and Harry S. Leahey, "Licensing Has a Role in Techology Strategic Planning" (*Business Development Review*, Fall 1986, pages 6-10); Willard Marcy, *Comparative Survey of Selected Private Sector Technology Transfer and Patent Management Organizations* (prepared for CUFT); and Mel Horwitch, "The Blending of Two Paradigms for Private-Sector Technology Strategy" (in Jerry Dermer, ed., *Competitiveness Through Technology*).

Practical advice on licensing is contained in the remarks by William Davis of Pfizer Incorporated on pages 84-88 of National Council of University Research Administrators, *The Private Sector/University Technology Alliance--Making It Work*; Robert Goldscheider; *Introduction to the Licensing of Laboratory Technology* (which was prepared for the FLC); Robert Goldscheider, *Technology Management Handbook*; and Tom Arnold and Tim Headley, "Factors in Pricing Technology Licenses" (*Les Nouvelles*, March 1987, pages 18-22).

Lastly, the private sector is beginning to identify its research needs through such things as Society of Manufacturing Engineers, *Directory of Manufacturing Research Needed by Industry*.