CONFERENCE PROCEEDINGS

RAND

Technology Transfer of Federally Funded R&D

Perspectives from a Forum

Mark Wang, Shari Pfleeger, David M. Adamson, Gabrielle Bloom, William Butz, Donna Fossum, Mihal Gross, Charles Kelley, Terrence Kelly, Aaron Kofner, Helga Rippen

RAND Science and Technology Policy Institute

C O N F E R E N C E   P R O C E E D I N G S

RAND

Technology Transfer of Federally Funded R&D

Perspectives from a Forum

Mark Wang, Shari Pfleeger, David M. Adamson, Gabrielle Bloom, William Butz, Donna Fossum, Mihal Gross, Charles Kelley, Terrence Kelly, Aaron Kofner, Helga Rippen

Prepared for the Office of Science and Technology Policy

RAND Science and Technology Policy Institute

The conference papers described in this report were prepared for the Office of Science and Technology Policy under Contract 9182731.

ISBN: 0-8330-3359-X

The RAND conference proceedings series makes it possible to publish conference papers and discussions quickly by forgoing formal review, editing, and reformatting. Proceedings may include materials as diverse as reproductions of briefing charts, talking points, or carefully written scientific papers. Citation and quotation is permitted, but it is advisable to check with authors before citing or quoting because of the informal nature of the material.

RAND is a nonprofit institution that helps improve policy and decisionmaking through research and analysis. RAND® is a registered trademark. RAND's publications do not necessarily reflect the opinions or policies of its research sponsors.

Published 2003 by RAND
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
201 North Craig Street, Suite 202, Pittsburgh, PA 15213-1516
RAND URL: http://www.rand.org/
To order RAND documents or to obtain additional information, contact Distribution Services: Telephone: (310) 451-7002; Fax: (310) 451-6915; Email: order@rand.org

Preface

About This Document

The President's Council of Advisors on Science and Technology (PCAST) has been assigned to submit a report to the President of the United States on ways to improve the transfer to the commercial sector of technologies developed with federal research and development (R&D) funding. In preparation for the PCAST report, RAND was asked to host a one-day forum on technology transfer. The forum was held on December 12, 2002, in RAND's Washington, D.C., office. The purpose of the forum was to elicit comments and discussion on technology transfer issues, in particular to gain a variety of perspectives on best practices. Representatives from all relevant organizations engaged in technology transfer were invited to share their ideas at the public forum or through written comments. Preregistration for the forum was conducted on-line; the registration form was directly linked to a brief questionnaire on technology transfer designed to elicit comments and to document experiences.

This document summarizes the proceedings of the forum. It presents an overview talk delivered by RAND and sums up the main themes that emerged from the forum discussion. It also incorporates, as appendices, background material developed by RAND and provided to forum participants.

About the S&T Policy Institute

Originally created by the U.S. Congress in 1991 as the Critical Technologies Institute and renamed in 1998, the Science and Technology Policy Institute is a federally funded research and development center sponsored by the National Science Foundation and managed by RAND. The Institute's mission is to help improve public policy by conducting objective, independent research and analysis on policy issues that involve science and technology. To this end, the Institute

- Supports the Office of Science and Technology Policy and other Executive Branch agencies, offices, and councils
- Helps science and technology decisionmakers understand the likely consequences of their decisions and choose among alternative policies

- Helps improve understanding in both the public and private sectors of the ways in which science and technology can better serve national objectives.

In carrying out its mission, the Institute consults broadly with representatives from private industry, institutions of higher education, and other nonprofit institutions. Inquiries regarding the Science and Technology Policy Institute may be directed to the following:

Helga Rippen
Director
Science and Technology Policy Institute
RAND
1200 South Hayes Street
Arlington, Virginia 22202-5050
rippen@rand.org

Contents

Preface ... iii

Contents ... v

Executive Summary ... vii
- Background ... viii
- Key Perspectives from the Technology Transfer Forum ... xi
- Directions for Future Research ... xiii

Acknowledgments ... xv

1. Introduction ... 1
   - The PCAST Technology Transfer Forum ... 1
   - Background ... 2
   - Organization of This Document ... 3

2. Overview of Technology Transfer ... 5
   - What is Technology Transfer? ... 5
   - The Federal R&D Enterprise ... 7
   - Laws Governing Technology Transfer ... 9
   - How Much Federal R&D Is Ripe for Technology Transfer? ... 14
   - Measurement Issues in Technology Transfer ... 17
   - Diffusing Technology Innovation and Commercializing Ideas ... 20
   - Lessons from Non-Federal Technology Transfer ... 22
   - Other Forms of Technology Transfer ... 25
   - Is There a Broader Role for the Federal Government in Technology Transfer? ... 26

3. Themes from the PCAST Technology Transfer Forum ... 29
   - Technology Transfer: Adjusting to the Policy Environment ... 29
   - General Views of Technology Transfer ... 30
   - Implementation of Technology Transfer ... 31
   - Steps for the Future ... 32
   - Summary ... 32

Appendix A. Conference Agenda ... 35

Appendix B. Summary of Technology Transfer Legislation ... 37

Appendix C. Measuring Technology Transfer ... 45

Appendix D. Toward Finding Best Practices ... 57

Appendix E. On-Line Questionnaire and Compilation of Responses ... 65

Appendix F. Excerpted Comments from the December 12, 2002, Forum ... 83

Bibliography ... 99

Executive Summary

The United States has long been a leader in creating and developing new technologies that advance understanding of the world around us, solve complex problems, keep the nation's industries competitive, and improve society's quality of life. By funding research, the federal government has played a major role in helping to create these new technologies. At the same time, the government has encouraged individuals and organizations to embrace and use knowledge that flows from federally funded research results to develop new products. This process is the essence of technology transfer. By understanding technology transfer, the government can increase the benefits it accrues from its investment in new technologies.

The President's Council of Advisors on Science and Technology (PCAST) was asked to examine the nature of technology transfer resulting from federally funded research and development (R&D). Generally speaking, technology transfer involves generating innovative ideas through the sharing of relevant knowledge and through the sharing of facilities among federal laboratories, universities, industry, and government, and commercializing those ideas in the form of goods and services. Often, the process of technology transfer uses technology, expertise, and facilities not only to solve a specific problem but also to facilitate its application to purposes not originally intended by the developing organization. In either case, these efforts can result in commercialization of a new product or process, or product and process improvements.

As part of its deliberations, PCAST asked RAND to host a one-day forum on the transfer of technologies developed with federal R&D funding. The forum, and in particular its open afternoon session for public comments, solicited input from participants on issues and best practices related to successful technology transfer. To attract a diverse set of participants with a wide range of viewpoints, announcements for the forum were posted in the Federal Register and distributed through e-mail to major groups involved in technology transfer, including universities, federal laboratories, government, industry, and the venture capital community. Additionally, for interested individuals and organizations who could not attend the forum, RAND developed an on-line questionnaire to collect information on their experiences with technology transfer and to solicit their thoughts on identification of best practices and the barriers to implementing those best practices.

Background

To help stimulate and structure discussion at the forum, RAND first presented an overview of technology transfer.

Overview of Technology Transfer

The overriding goal of any technology transfer is its successful adoption by a large majority of consumers who can use the technology. However, because every organization has its own goals and culture, there is no single technology transfer process that fits all organizations and occasions. Rather, there are several key steps or activities included in most technology transfer processes, and an individual process is tailored to fit organizational needs.

Figure S.1 presents a schematic overview of the main activities involved in the process of technology transfer.

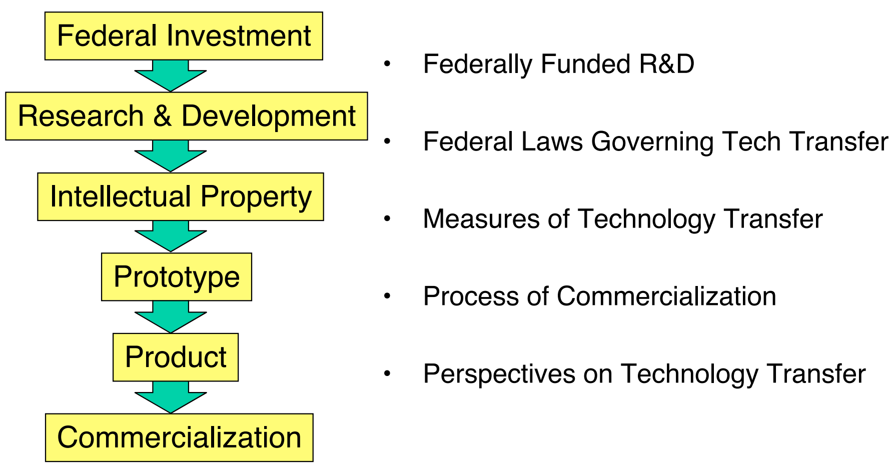

Figure S. 1—Schematic Overview of Technology Transfer Activities

This schematic view presents technology transfer in terms of its ultimate goal: commercialization, which involves taking intellectual property that derives from federally funded R&D at universities or federal laboratories, developing products, and then commercializing them. This chain of activities and the expectation that technology transfer will lead to commercialization is aimed at improving the nation's economic well-being and quality of life.

This framework is, of course, oversimplified. Innovation and insights on how to use old things in new ways, or how to use new ideas to solve old problems, may not be predictable or linear.

There may be evolutionary advances to existing technologies, or revolutionary technologies that displace or disrupt other technologies or existing ways of doing things.[1,2] There is also considerable iteration among the various activities. The process also typically involves a variety of players, from transferors who create the technology and prove the concept, to those who embed the technology in a useful product, service, tool, or practice, and finally to transferees who embrace it, further develop it, commercialize it, and ultimately use it.

Federal R&D Funding and Performers

To understand the earliest stages of technology transfer, it is useful to first understand the nature of federal investment in R&D. Annually, the U.S. government invests roughly $80 billion in federally funded research and development. Funding is dominated by the Department of Defense (DoD) and the Department of Health and Human Services (HHS), which includes the National Institutes of Health (NIH). Together with the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the National Science Foundation (NSF), these top five agencies fund 95 percent of the annual federal investment in R&D. Federally funded R&D is performed by many types of institutions. The federal laboratories together perform about 30 percent of the funded R&D, followed by universities which account for about 25 percent. Large and small businesses perform about 40 percent of federally funded research and development.

Figure S.2 displays a breakdown of the federal investment by funding agency and by the entities performing the research and development. The nonU.S. government operated federal laboratories (nonintramural laboratories) are represented by the top bar in the figure, which shows the DOE was the most significant R&D funding agency in that area. The second bar displays the government-owned government-operated (GOGO) federal labs (intramural labs). There, roughly half the funding comes from the DoD. Funding at large businesses and small businesses also largely comes from the DoD. Funding at universities and colleges is predominantly from the HHS. Note that the only sizable portion of research funded by the NSF is performed at universities.

---

[1] See Schumpter (1942) for a discussion of his concept of “creative destruction.”

[2] Christensen (1997).

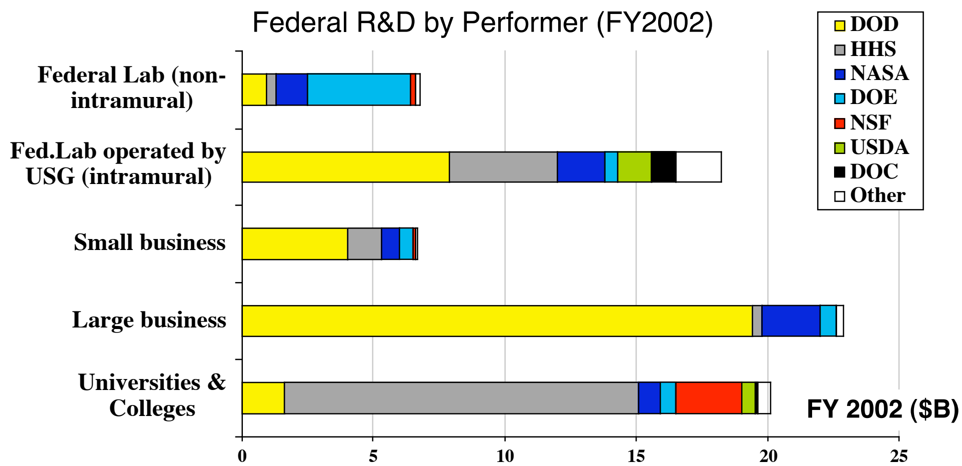

Figure S.2—Federal R&D by Funding Agency and by Performer (FY2002 $B)

Federal Laws Governing Technology Transfer

Concerns about U.S. global competitiveness and a rising Japan in 1980 motivated Congress to pass legislation intended to increase the movement of university knowledge and ideas into commercial innovations and products. Prior to 1980, universities and other research institutions had little incentive to commercialize their research, given that the patent rights belonged to the federal funding agency. The federal policies that increase technology transfer to the private sector are set forth in a collection of legislation and Executive Orders (EOs). These laws and EOs are primarily concerned with intellectual property rights but also govern other aspects of the larger process of transferring technology created with federal funds. This collection of laws includes three pieces of legislation cumulatively known as the Bayh-Dole Act: the University and Small Business Patent Procedures Act, the Trademark Clarification Act, and Executive Order 12591. Another important piece of legislation, the Stevenson-Wydler Act, gives federal agencies responsibility for transferring intramural federal R&D results to the private sector. Two important R&D agencies, NASA and the DOE, are covered by separate acts, but federal policy guidance has in effect brought them in line with Stevenson-Wydler.

Measures of Success

Because technology transfer involves so many different individuals and organizations and their diverse needs, it is difficult to define universally appropriate measures of transfer activity or effectiveness. Indeed, it is unlikely that all federal laboratories, universities, and corporations perform equally well with respect to any given measure of success. However, there has been meaningful work on defining metrics for and success in technology transfer. The Interagency Committee of Federal Technology Transfer, chaired by the Department of Commerce (DOC), has identified key mechanisms for successful transfer. These include licensing, Cooperative Research and Development Agreements (CRADAs), technical assistance and consulting, reimbursable work for nonfederal partners, the use of facilities, exchange programs and collegial interchange, publications, and conferences.

Beyond anecdotal information, practitioners and scholars of technology transfer have developed and used diverse metrics that are usefully described in seven categories: (1) science, technology, engineering, and medical school graduates taking jobs in the technology sector; (2) patents; (3) manufacturing innovations; (4) innovation networks; (5) Web hits to a science database; (6) transfer mechanisms; and (7) knowledge spillovers.

No particular metric is appropriate for all applications, nor is any particular analytical tool correct for answering every question. Yet, the principal findings from academic research of technology transfer, even from a field barely 20 years old, are already varied and useful. They point in some instances to patterns worthy of close attention from practitioners of technology transfer and from policymakers.

Key Perspectives from the Technology Transfer Forum

In order to identify important issues and best practices, a Technology Transfer Forum was held at RAND's Washington, D.C., office on December 12, 2002, to raise as many issues and perspectives as possible on the topic of technology transfer. This forum included a roundtable discussion featuring the participation of technology transfer experts representing research universities, federal laboratories, the U.S. government, and various industries. A significant portion of the agenda was devoted to an open forum session at which attendees could make public comments. An open discussion period also provided an opportunity for additional comments. Many individuals who were unable to attend the forum could submit comments from an on-line questionnaire-and-comments form.

Several themes emerged from discussions at the forum and subsequent questionnaire submissions. The discussion that follows represents RAND's summary of the main issues and perceptions that emerged at the forum. Note that these are perceptions only and not necessarily fact, although the opinions expressed here may help to suggest where further research may be most valuable.

Technology Transfer: Adjusting to the Policy Environment

- Participants generally agreed that improving technology transfer involves a steep learning curve. It has taken decades for organizations to learn how to operate successful transfer programs.
- In part because of the length of this learning curve, many forum panelists and attendees expressed the belief that technology transfer legislation should not be altered.
- There is a broad perception that the U.S. R&D landscape has changed in the past two decades. For instance, the relative share of R&D funded by government is believed to have shifted, altering the balance of basic versus applied research, and a short-term focus versus a long-term focus.

General Views of Technology Transfer

- Panelists and attendees noted that technology transfer should be viewed broadly. A framework including federal investment, legislation, and commercialization seemed useful.
- Many forum attendees discussed technology transfer within a global context. U.S. competitiveness and an increasingly global economy spurred these comments. Industry partnerships with foreign research institutions was also a recurring point of discussion.
- Successful commercialization requires significantly more than a good idea or new technology. Developing a successful product requires, among other things, effective management, strategy, timing, and marketing. Coordinating among many organizations, some with widely varying missions, is a significant challenge.

Implementation of Technology Transfer

- Many attendees urged that recommendations to improve technology transfer, particularly of implementation issues, be tailored to specific circumstances. The processes that work for one industry or institution may not be applicable to another.
- Employees at the federal laboratories feel less incentive than their counterparts in universities or in industry to contribute to technology transfer. Lack of consulting time, royalties, and equity in startups were among the issues raised.
- The implementation of technology transfer is not uniform: Technology licensing offices operate in diverse ways and do not apply Bayh-Dole uniformly.
- The increase in interdisciplinary and jointly sponsored research sometimes creates confusion when ownership of intellectual property is not clear.
- Resources early in the technology transfer process are sought by all parties. Lack of these early resources hinders technology and market development, and hinders patent and licensing processes.

Steps for the Future

- Many attendees recommended the development of training tools and education courses on technology transfer, including explanations of the use of various technology transfer mechanisms.
- Homeland security issues were raised by some forum participants, in the context of planning for increased research and development and moving technologies into public use.
- Some attendees suggested examining how technology transfer is accomplished in other countries. In the U.K., for example, many companies are invited to bring their R&D efforts into university settings where they can be nurtured by universities.
- Many attendees agreed that technology transfer, and the many issues that were raised, require further research to develop and improve metrics, especially those that measure benefits to the end user.

Directions for Future Research

Based on the themes that emerged from the forum, RAND identified a range of areas in which increased knowledge might help improve federal technology transfer. In assessing the government's return on its technology investments, much of the current discussion has focused on existing legislation and how it affects the success of technology transfer. However, no set of best practices has been proposed or adopted. Interesting observations and anecdotes give some clues as to what works well and give some basis for deliberations, but they do not constitute a body of systematic knowledge from which best practices can be derived. A clearer conceptual framework, supported by carefully conceived and collected data, is needed to support a more rigorous study of which transfer practices have been effective and in which contexts. Four issues in particular stand out for future research:

- First, given the various ways in which technology can be transferred and the numerous organizations involved in those transfers, what measures or combinations of measures are best for evaluating, advancing, and monitoring progress of technology transfer? For those metrics or combinations of metrics, what goals would be reasonable?
- Second, using the metrics developed as described above, how do the various federal agencies compare in their ability to transfer technology, and which practices can and should be emulated by others?
- Third, foreign universities and laboratories have active programs to license intellectual property and transfer technology. What might we learn from an examination of foreign technology transfer practices, and which ones might be profitably adopted by the United States?
- Fourth, what can we learn from the private-sector experience with technology transfer and what might be applicable for federal-to-private technology transfer?

Acknowledgments

This project was conducted by and documented by an interdisciplinary team of researchers at the RAND Science and Technology Policy Institute. It would not have been possible without the support and assistance from many individuals and organizations.

RAND provided analytic support to OSTP and PCAST. The guidance received was invaluable, particularly in preparation for the December 12, 2002, forum. From OSTP, we thank Richard Russell for making opening remarks at the forum; we thank Stan Sokul, and Amy Flatten for their help in defining this project and facilitating announcements. PCAST members Wayne Clough and Kathy Behrens led several teleconferences in developing the agenda, particularly the roundtable and panelist discussions. Along with Dr. Clough, Luis Proenza co-chaired the afternoon open forum and post-forum meeting with the RAND research team. We also thank Marjorie Burdetsky from Capital Meeting Planning for helping coordinate PCAST travel and other logistics.

The roundtable panelists and their respective organizations deserve special thanks for participating and sharing their expertise on technology transfer. The roundtable discussion and first-hand experiences were the highlight of the forum. The panel members included David Beier (Hogan and Hartson), Richard Brenner (Department of Agriculture), Lita Nelsen (MIT), Kate Phillips (COGR), Frank Pita (Semiconductor Research Corporation), Al Romig (Sandia National Laboratories), and Juliana Shei (General Electric). Bruce Mehlman (Department of Commerce) moderated the panel on short notice, and earlier had hosted a meeting with others at the Department of Commerce including Benjamin Wu and Mark Boroush.

Although they are too numerous to list individually, we also thank those in attendance at the December 12 forum for their input during the forum's open session and discussion. It is clear from the registration list that the forum attracted major stakeholders in technology transfer: government agencies, university technology licensing officers, academic scholars of technology transfer, federally funded researchers, federal laboratories, big- and small- industry and federal- and industry-consortia, intellectual property attorneys, venture capitalists, and entrepreneurs. Those who attended and many more who did not attend also submitted on-line and written statements, many of which are incorporated in this document.

Properly producing a public document requires the review of many stakeholders on an issue as broad as technology transfer. The authors thank Wayne Clough, Gib Marguth, and Kate Phillips for their comments that helped improve this report. We also appreciate the time spent reviewing the document by the roundtable panelists and others from the Federal Laboratory Consortium, the Association of University Technology Managers, and the Industrial Research Institute. Within RAND, we thank Parry Norling, Debra Knopman, Richard Silberglitt, and Caroline Wagner for their reviews of various versions of this document.

Within RAND, the authors thank Darlette Gayle, Nora Wolverton, and Lisa Sheldone for administrative and other support. Gail Kouril contributed to the literature search, members of the RAND survey research group crafted a questionnaire, Phyllis Gilmore helped get it on-line, and Nancy DelFavero edited the final document. Irene Brahmakulam and Marschelle Bowler helped compile this document's extensive bibliography. The authors remain responsible for any errors or omissions.

1. Introduction

The President's Council of Advisors on Science and Technology (PCAST) will soon present a report to President Bush on ways to improve the transfer of technologies that are developed with federal research and development (R&D) funding to the commercial sector. The federal government makes a substantial annual investment in R&D—$80 billion in fiscal year (FY) 2002 alone.[3] This federal investment has explicit goals and is intended to produce both direct and indirect results in the form of deliverables specified in individual contracts and grants. But implicit in the federal investment is an additional rationale: transferring the results of some portion of this R&D to nonfederal organizations, and in particular private ones, that can generate innovations or spin-offs suitable for commercialization and trade. Ultimately, this federal investment is aimed at improving the U.S. economy, national security, and quality of life.

The PCAST Technology Transfer Forum

As part of the preparation for the PCAST report, and to shed some light on the topic of technology transfer, RAND was asked to host a one-day forum on the transfer of technologies that are developed with federal R&D funding. The forum, and in particular its open afternoon session for public comments, solicited input from participants on issues and best practices related to successful technology transfer.

RAND hosted the Technology Transfer Forum on December 12, 2002, at its Washington, D.C., office.[4] To attract a diverse set of participants with a wide range of viewpoints, announcements for the forum were posted in the Federal Register and distributed through e-mail to major groups involved in technology transfer, including universities, federal laboratories, government, industry, and the venture capital community. Preregistration for the forum was conducted on-line; the registration form was directly linked to a brief questionnaire on technology transfer designed to elicit comments and to document experiences. Additionally, for interested individuals and organizations who could not attend the forum, RAND developed an on-line

[3] This figure represents obligations. The Bush Administration's FY 2003 budget requested approximately $110 billion for R&D. The R&D dollars are for the "conduct of R&D" and not total R&D. Total R&D includes the conduct of R&D as well as money spent on "R&D equipment" and "R&D facilities." Because the latter two categories are not relevant to technology transfer, the dollars associated with those categories were not included in this report.

[4] The forum's agenda is in Appendix A.

questionnaire to collect information on their experiences with technology transfer and to solicit their thoughts on best practices and the barriers to implementing those best practices.

Background

The United States has long been a leader in creating and developing new technologies that advance understanding of the world around us, solve complex problems, keep the nation's industries competitive, and improve society's quality of life. By funding research, the federal government has played a major role in helping to create these new technologies. At the same time, the government has encouraged individuals and organizations to embrace and use knowledge that flows from federally funded research results to develop new products. How do new or improved technologies progress from creation (of an idea or piece of knowledge) to proof of concept (through a prototype, for example) to adoption (as a commercial product or practice) to diffusion of the technologies? This process is the essence of technology transfer. By understanding technology transfer, the government can increase the benefits it accrues from its investment in new technologies.

Many individuals and institutions are involved in technology transfer, and it is important to understand their role in a successful transfer of technology. Federally funded R&D is sponsored by many government agencies, and it is conducted by a wide range of performers, including universities, federal laboratories, and both large and small industries. Increasingly, interdisciplinary and inter-institutional research blurs the boundaries among traditionally separated fields. So, too, do joint appointments for faculty or federal employees, partnerships with state and local agencies, venture capital and investment community development of new businesses, cooperative agreements with industry, and even international consortia to build the world's most ambitious research facilities.

Across these various groups, the incentives for rewarding technology transfer vary, and procedures for protecting, licensing, and commercializing intellectual property are not always clear. Indeed, the participants' competing goals have raised perceptions of conflicts of interest, counterproductive behaviors, and even the possibility that foreign corporations derive disproportionate benefit from U.S.-funded research.[5] These factors, along with the different contexts in which technology transfer is done, make it challenging to set goals, define success, and measure the degree to which technology transfer meets its goals. Even when it can be assumed that technology transfer is operating well according to some measure, we must ask how to improve the return on federal investment. Study of past practice suggests candidates for implementing this improvement, ranging from offering various financial incentives to matching researchers with those individuals and organizations best suited to commercialize their ideas.

Facilitating technology transfer, understanding its role, and evaluating its impact all require measurement. Thus, the difficult tasks of specifying appropriate metrics and collecting data on the metrics are important and necessary. Difficulties arise to some degree in the context-dependence of the transfer process. The many ways that technology transfer occurs; the different persons and institutions involved in the transfer; the complex scientific, technological, and organizational processes that produce it; and its varied manifestations in processes and products are all contextual characteristics suggesting that a single, all-purpose metric of success is impossible. Moreover, a single metric may be undesirable or impractical since the benefits can accrue to diffuse populations and along diverse pathways, in some cases the benefits do not emerge until well after the technology is deployed.

Organization of This Document

Chapter 2 summarizes an overview of technology transfer presented by RAND to the forum participants. The purpose of the presentation was to describe the status of federally funded R&D technology transfer and to highlight important issues for discussion. Chapter 3 presents the major themes that emerged from the discussions of the forum participants.

Appendix A presents the forum's agenda. Appendix B summarizes legislation that governs technology transfer. Appendix C provides additional background information and observations on measuring the success of technology transfer. Appendix D discusses specific issues related to identifying best practices for transferring technology. Appendix E presents the on-line questionnaire and results. Appendix F lists excerpted comments from the forum on various aspects of technology transfer.

---

[5] Marcus (1999) and Reed and Schriesheim (1996).

2. Overview of Technology Transfer

This chapter presents an overview of technology transfer and is based on a RAND presentation delivered at the December 12, 2002, forum. By design, the subject is discussed broadly. The intent was allow all stakeholders present at the forum the opportunity to recognize their role in the process and discuss methods for facilitating improvements.

What is Technology Transfer?

The following are three definitions of technology transfer from major sources, each subtly different, but with a similar message:

- The process of utilizing technology, expertise, know-how or facilities for a purpose not originally intended by the developing organization. Technology transfers can result in commercialization or product/process improvement.

  — *National Technology Transfer Center (NTTC)*

- The process by which existing knowledge, facilities, or capabilities developed under federal R&D funding are utilized to fulfill public and private needs.

  —*Federal Laboratory Consortium (FLC)*

- The formal transfer of new discoveries and innovations resulting from scientific research conducted at universities and nonprofit research institutions to the commercial sector for public benefit.

  —*Association of University Technology Managers (AUTM)*

The first statement from the NTTC includes the phrase "not originally intended by the developing organization," implying that the focus of technology transfer is for indirect benefit.

The second definition is from the Federal Laboratory Consortium. Note that the phrase from the NTTC definition regarding unintended purposes does not appear in the FLC statement. Indeed the purpose of a lot of federal laboratory research and development is to accomplish something specific, which may also potentially lead to technology transfer.

And the last statement from the Association of University Technology Managers focuses on commercialization (i.e., bringing the benefits of federal research and development (R&D), and the intellectual properties and technologies developed as a result of that research into new products).

Although the three statements have similarities, their variations suggest that technology transfer means different things to different people. Therefore, this discussion treats the subject very broadly, allowing for individual and organizational differences. Similarly, metrics for technology transfer success and best practice are left open for interpretation and discussion.[6] Technology transfer is generally accepted to be beneficial, even if a specific definition may not necessarily be agreed upon.

Persons speaking before the December forum were welcome to define technology transfer in whatever term was most comfortable and most useful to them and their organization.

This discussion of technology transfer follows the schematic overview presented in Figure 2.1. It shows technology transfer progressing from federally funded research through commercialization--that is, taking intellectual property that derives from federally funded research at universities or federal laboratories, developing products, and then selling them. This chain of activities and the expectation that technology transfer will lead to commercialization is aimed at improving the nation's economic well-being and quality of life.

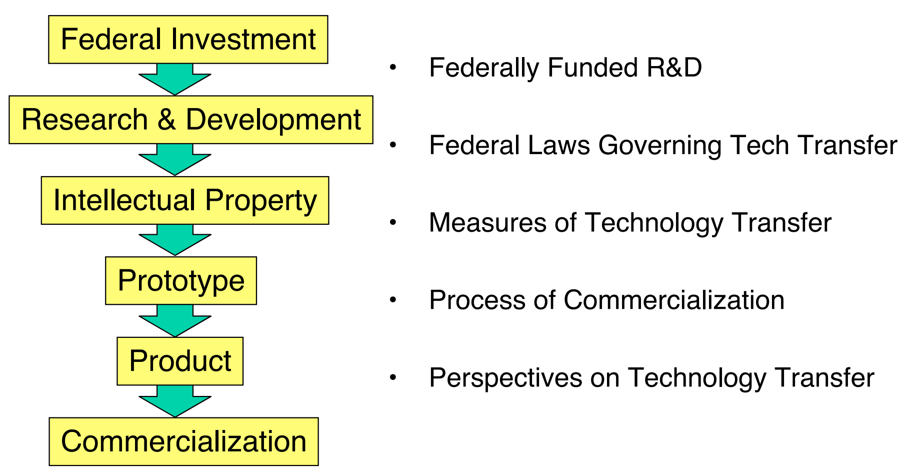

Figure 2.1— Schematic Overview of Technology Transfer Activities

This framework is, of course, oversimplified. Innovation and insights on how to use old things in new ways, or how to use new ideas to solve old problems, may not be predictable or linear. There may be evolutionary advances in existing technologies, or revolutionary technologies that

[6] The bi-annual Department of Commerce report on Federal Laboratory technology transfer activities has a similar approach, allowing different laboratories to describe their activities in individual presentations.

displace or disrupt other technologies or existing ways of doing things.[7, 8] There is also a lot of iteration between the various stages. The process also typically involves a variety of players, from transferors who create the technology and prove the concept, to those who embed the technology in a useful product, service, tool or practice, and finally to transferees who embrace it, further develop it, commercialize it, and ultimately use it.

For purposes of this overview, this framework enables discussion to focus on the different stages of technology transfer and the transitions between each stage (represented by the arrows between the boxes in Figure 2.1). There have been comments about a lack of clarity at the transitions, or various stages, and comments about incompatible incentives between the stages.

The framework in Figure 2.1 also serves as an outline of this chapter. The chapter begins with a discussion of the federally funded R&D portfolio. It then presents the laws governing technology transfer, which focus largely on the transfer or management of intellectual property, ownership issues, patenting, and mechanisms for licensing. This discussion is followed by a summary of what we know about measures of technology transfer and the process of commercialization.

The Federal R&D Enterprise

First, we will review the federally funded R&D enterprise, noting that it involves many funders and performers, as shown in Figure 2.2. Annually, the federal government invests roughly $80 billion in federally funded research and development. As seen in the pie chart on the left of the figure, funding is dominated by the Department of Defense (DoD) and the Department of Health and Human Services (HHS), which includes the National Institutes of Health (NIH). Together with the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the National Science Foundation (NSF), these top five funders account for 95 percent of the annual federal investment in R&D.

---

[7] Schumpter, Joseph (1942) concept of "creative destruction."
[8] Christensen (1997).

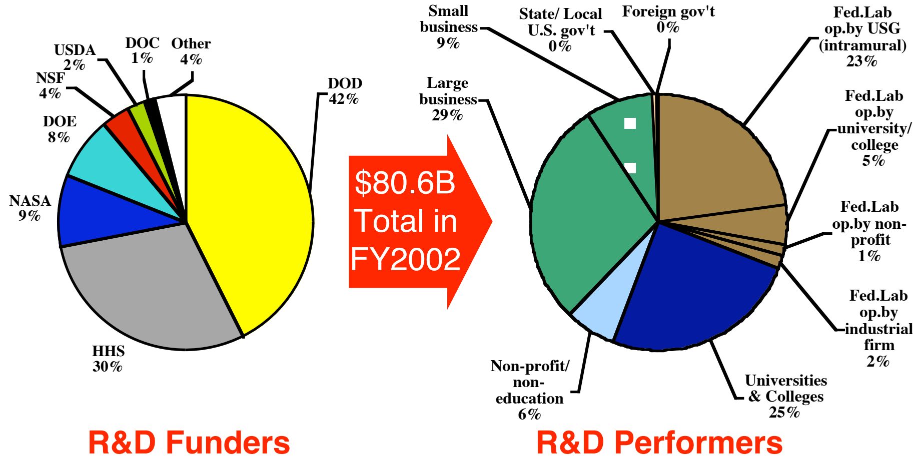

Figure 2.2—Annual Federal R&D Obligations

Where does this money go? The pie chart on the right in the figure shows the $80 billion amount broken out by research performers. The federal laboratories together account for about 30 percent of the funded R&D, followed by universities which account for about 25 percent. Large and small businesses receive about 40 percent of federal research and development.

Figure 2.3 displays this federal investment a different way. Here, funding for performers of federal research and development is displayed based on the funder. The nonU.S. government operated labs (non-intramural labs) are represented by the top bar, which shows that the DOE was the most significant R&D funding agency in that area.

The second bar displays the government-owned government-operated (GOGO) federal labs (i.e., intramural labs). In those labs, roughly half of R&D funding is from the defense department. Funding for large and small business is also primarily from the DoD.

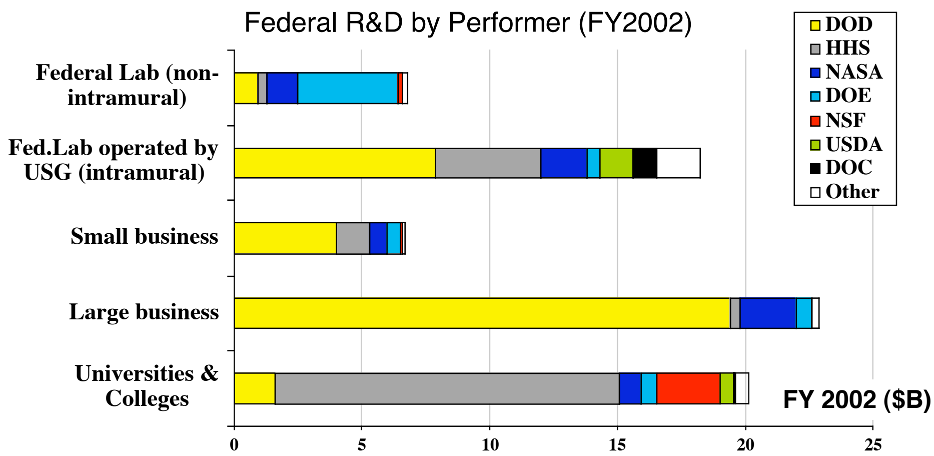

Figure 2.3—Federal R&D by Funding Agency and by Performer (FY2002 $B)

Federal R&D funding at universities and colleges predominantly comes from the HHS. Note that the only sizable portion of research funded by the NSF is performed at universities.

In summary, the funding profiles differ from performer to performer, and the perspectives of each institution regarding technology transfer may differ accordingly. Later in the chapter, we discuss how these funding profiles may determine different expectations for technology transfer depending for different disciplines and research institutions.

Laws Governing Technology Transfer

A brief discussion of a few federal laws governing technology transfer is important to understanding the current mechanisms and processes for transfer.[9] In 1980, concerns over U.S. global competitiveness and particularly the rising competition from Japan motivated Congress to facilitate the commercialization of university research results and ideas. Prior to passage of the Bayh-Dole Act, intellectual property from federally funded research was the property of the federal agency funder. Universities had little incentive to commercialize research ideas and produced only 250 patents a year.[10] Capital markets also stayed on the sidelines, making it difficult to obtain the necessary investments to develop prototypes and the companies to produce commercial products. Technology transfer legislation in 1980 changed all of this by giving universities and national laboratories patent ownership and incentives to commercialize federally funded research results. With patent ownership clarified, crucial capital investments were also

[9] A more complete listing of legislation governing technology transfer can be found in Appendix B.

more secure and viable because the clarified ownership reduced the risk of lost investments to outsiders who might claim superior ownership rights.

Current federal technology transfer policies focus on the first three stages of the technology transfer framework shown in figure 2.4: investment, R&D, and intellectual property rights. Intellectual property rights in particular are at the center of federal policy. The federal government's principal means for promoting technology transfer is to grant intellectual property rights to non-federal performers of federally funded R&D, such as universities, private firms, and other entities. With property rights, performers of R&D are free to commercialize the results of their R&D activities and reap the economic benefits. Further, the United States may also benefit from the increased quality of life, the increased national security, and other less tangible benefits.

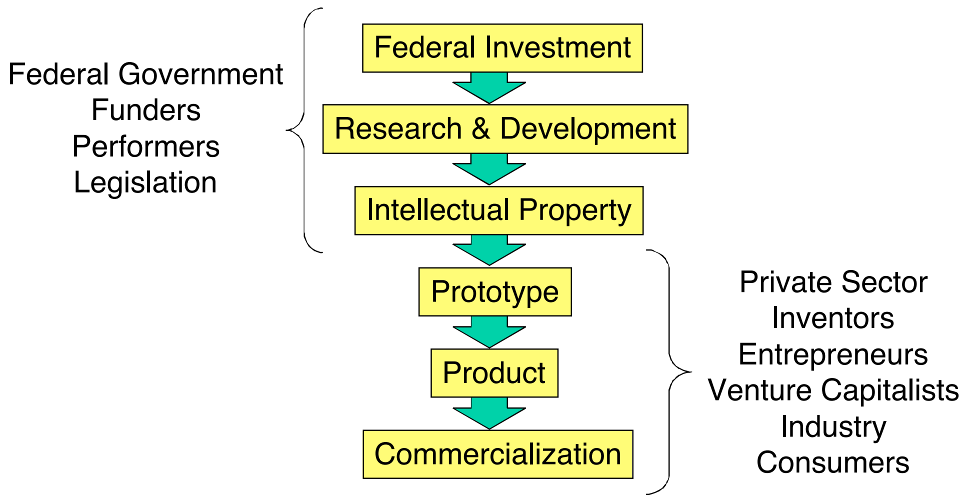

Figure 2.4—Federal Laws Drive the Early Stages of the Technology Transfer Process

The actors listed in the bottom half of Figure 2.4, including the private-sector organizations involved with prototyping and commercializing new products, are not directly within the immediate purview of federal technology transfer laws. Corporations and consumers involved with the stages of prototyping, development, and commercialization are affected by federal tax laws and regulations which influence technology transfer. For instance, most universities and many research institutions are constituted as nonprofit entities. The tax code governs the kinds of research in which tax-exempt organizations usually engage, as well as the terms of licensing agreements with for-profit corporations.[11] Also, bond financing is a large part of university

[10] Press and Washburn (2000), p.39.

[11] See IRS Publication 557 (Rev. July 2001), Cat. No. 46573C, “Tax-Exempt Status for Your Organization,” p. 24, for discussion of nonprofit “scientific organizations.”

construction, adding other constraints.[12] Property and income taxes and various federal regulations indirectly affect many corporations and consumers involved with technology transfer, but they are out of the scope of this report.

- "Bayh-Dole" Act
  - University & Small Business Patent Procedures Act (1980)
  - Trademark Clarification Act (1984)
  - Executive Order 12591 (1987)
- "Stevenson-Wydler" Act
  - Technology Innovation Act (1980)
  - Federal Technology Transfer Act (1986)
  - National Competitiveness Technology Transfer Act (1989)
- Other
  - (NASA) National Aeronautics and Space Act (1958)
  - (DoE) Atomic Energy Act (1954), Non-Nuclear Energy Research Act (1974)

Figure 2.5—Laws Facilitating Technology Transfer

A collection of laws (shown in Figure 2.5) governs the transition between the top half and the bottom half of the framework shown in Figure 2.4. The major legislation governing federal technology transfer is the Bayh-Dole Act. What is typically referred to as "Bayh-Dole" is actually the cumulative provisions of at least two major laws, their subsequent amendments, and one Executive Order (EO). The major laws and EO, discussed in more detail below, are The University and Small Business Patent Procedures Act of 1980, the Trademark Clarification Act of 1984, and Executive Order 12591 (1987). The intent of these laws and this EO is to enable non-federal performers of R&D to commercialize inventions developed with federal funds.

The University and Small Business Patent Procedures Act of 1980

The original Bayh-Dole legislation was adopted in 1980. Officially titled The University and Small Business Patent Procedures Act (USBPPA), this law permits small businesses and some nonprofit organizations, including universities, to retain patent rights to inventions created with federal R&D funds. This act also grants R&D performers the ability to claim intellectual property rights in nonpatentable data, such as trade secrets generated with federal funds.

[12] See IRS Revenue Procedure 97-14, 1997-5 I.R.B. 20, Section 5 on "Tax-Exempt Bonds; Private Activity Bonds."

Trademark Clarification Act of 1984

The Trademark Clarification Act (TCA) of 1984 amended the original Bayh-Dole Act to extend the force of its technology transfer provisions to federal laboratories that are owned by the federal government but operated under contract by nonfederal entities (i.e., government-owned contractor-operated, or GOCOs). Many of these GOCOs are also federally funded research and development centers (FFRDCs). This act permits the operators of these federal laboratories to patent and/or license technologies that the laboratories develop. It also permits the contractors operating these laboratories to retain royalties generated from their licenses to support additional R&D at their laboratories. However, this activity is sometimes constrained by other legislation. For example, although all of the Department of Energy's (DOE's) GOCO laboratories are technically subject to the provisions of Bayh-Dole via the TCA, the DOE has effectively brought its technology transfer activities under the provisions of the Stevenson-Wydler Technology Innovation Act (see below) using the provisions of the management contracts governing the operations of each of these laboratories.

Executive Order 12591 (1987)

The Executive Order 12591, "Facilitating Access to Science and Technology," extends the provisions of the Bayh-Dole Act to large businesses conducting R&D with federal funds. Although this EO was not formally confirmed until 1987, its substance was authorized informally by President Reagan in 1983. This EO also changes the authority of federal laboratories to license their inventions, which is contained in Stevenson-Wydler as amended (see below), from permissive to mandatory.

Stevenson-Wydler Technology Innovation Act of 1980

The Stevenson-Wydler Technology Innovation Act of 1980 governs technologies resulting from R&D conducted by federal employees at federally operated laboratories (in other words, R&D performed intramurally). This act also gives federal agencies a continuing responsibility for transferring technology to non-federal entities. It requires each agency to establish an Office of Research and Technology Applications (ORTA) to promote the transfer of technology to non-federal entities. As amended in 1986, Stevenson-Wydler allows federally operated laboratories to license their inventions and to keep all of the royalties generated from the licenses after sharing at least 15 percent of the royalties with the federal employee(s)-inventor(s). Because Stevenson-Wydler does not address the actual mechanics of patenting and licensing, these activities in federally operated laboratories are governed by the provisions of Bayh-Dole as amended. In addition, the intramural R&D activities of the National Aeronautics and Space Administration (NASA) and the Department of Energy (DOE) are not covered by the provisions of Stevenson-Wydler. Instead, they are governed by the provisions of the Space Act (for NASA), the Atomic Energy Commission Act (for DOE's nuclear-technology transfer), and the Federal Non-nuclear Energy Research Act (for DOE's non-nuclear technology transfer).

National Aeronautics and Space Act of 1958

The National Aeronautics and Space Act of 1958 (often referred to simply as the "Space Act"), which established NASA in that year, has been amended multiple times in the ensuing years. Since its passage, the provisions of the Space Act that govern technology transfer have been largely overtaken by the provisions of Bayh-Dole and Stevenson-Wydler. The Space Act still governs NASA's technology transfer duties with respect to technology generated from R&D conducted directly by NASA employees (i.e., NASA's intramural R&D). With respect to these latter R&D activities, the Space Act requires that the NASA Administrator take title to all technologies invented by NASA employees. However, it gives the Administrator wide latitude to waive NASA's rights to these technologies if doing so better serves the interests of the United States.

Atomic Energy Act (1954) and Non-Nuclear Energy Research and Development Act of 1974

Like NASA, DOE had legal authorities in place prior to the enactment of Bayh-Dole and Stevenson-Wydler that continue to govern the technology transfer activities related to inventions resulting from DOE's intramural R&D. Similar to the situation with NASA, the Non-Nuclear Energy Research and Development Act of 1974 (NNERA) requires that the Secretary of Energy take title to all non-nuclear technologies invented by DOE employees, but it gives the Secretary wide latitude to waive DOE's rights to these technologies if doing so better serves the interests of the United States. The Atomic Energy Act (AEA) also requires the Secretary of Energy to take title to all nuclear technologies invented by DOE employees, but it also gives the Secretary the right to waive DOE's rights to these technologies.

As can be clearly seen by Figure 2.6, among all the legislation governing federal technology transfer, the Bayh-Dole Act governs the vast majority of federally funded R&D.

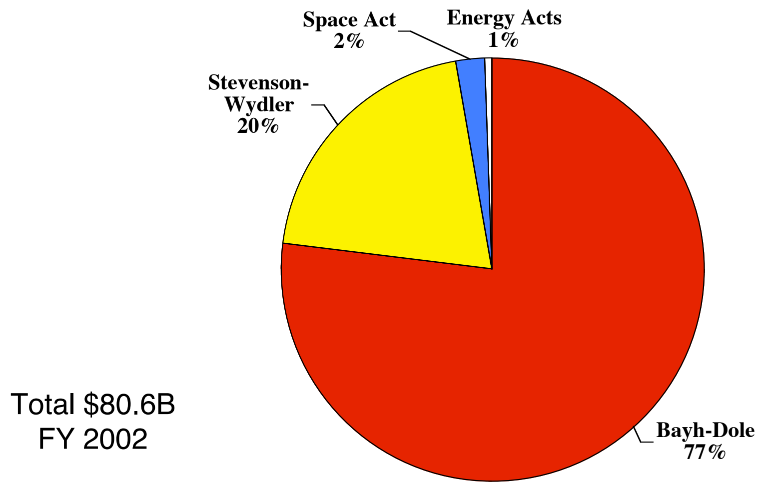

Figure 2.6— Bayh-Dole Governs Technology Transfer of Most Federal R&D Funds

An Ambiguity in Federal Policy

All federal technology transfer provisions are based on the institutional status of the party performing the federally funded R&D.[13] The provisions assume that performers of R&D are affiliated with only a single R&D institution. However, joint appointments between institutions are becoming increasingly common. For example, a federally funded researcher on the faculty of a university may also belong to the research staff at a federal laboratory. Consequently, technologies created by such researchers are "claimable" by two different types of R&D institutions that are governed by two different federal technology transfer provisions. Because the royalties resulting from the licensing of such technologies can be substantial, institutions are unlikely to forgo them willingly. In these situations, legal complications over intellectual property rights could ensue.

How Much Federal R&D Is Ripe for Technology Transfer?

Not all federal R&D is equally likely to produce transferable technologies. Federally funded R&D is divided into three categories: basic research, applied research, and development. The

[13]Foreign governments also carry out a small percentage of federal R&D–less than 1 percent. Foreign government performers are not covered under any of the federal technology transfer provisions.

latter includes both defense and non-defense development. Of these categories, applied research and non-defense development carry the highest expectations for technology transfer.

• Basic Research	30%
• Development: Weapon and defense-related systems	30%
• Applied Research and other Development	40%

Figure 2.7—Less than Half of Federally Funded R&D Is Applied Research

Basic research may have lower expectations for technology transfer. This is not to suggest that there is no technology transfer from basic research, but that the study of basic phenomena implies that the benefits are going to accrue over a much longer term, and perhaps be more indirect than the benefits that accrue from applied research or development.

And aside from dual-use technologies, defense research and development is really not intended for technology transfer. In fact, some weapons facilities are designed to keep information from being disseminated. Those facilities are prohibited from sharing technologies or intellectual property.

The highest expectations for technology transfer, therefore, apply to only about 40 percent of the federally funded R&D portfolio--in applied research and other non-defense development (see Figure 2.7). Again, this is not to imply that basic research has no expectations of commercialization. Indeed, basic research may stimulate applied research, which may inspire more basic research. Indeed, the distinctions between basic versus applied research are more shades of gray than they are black and white.

Keeping these qualifications in mind, Figure 2.8 displays the total $80.6 billion research and development portfolio by the various funding agencies and categories of funding. DoD dominates in funding; however, most of that funding is in defense-related or weapon systems development. Basic research and applied research and other development is also displayed for each funder.

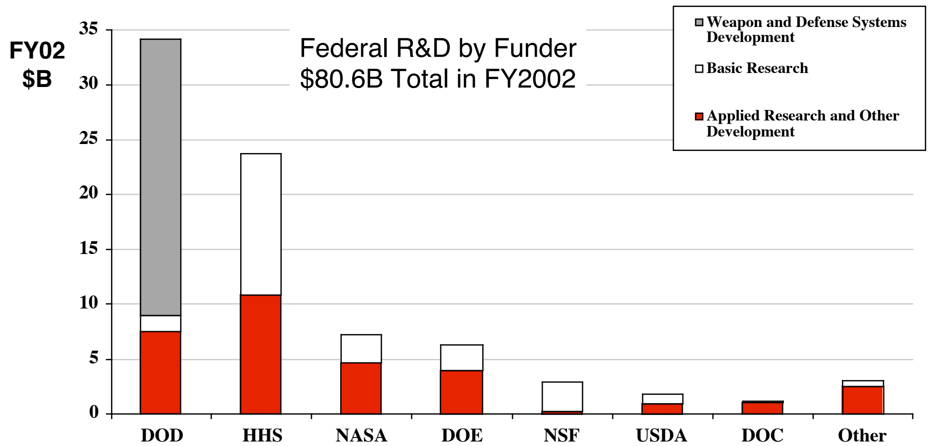

Figure 2.8— Civilian Agencies Have the Most Funding in R&D That Is Ripe for Technology Transfer

The area most ripe for technology transfer, applied research, is led by HHS and the civilian agencies. Earlier, we noted that most HHS funding goes to universities, and this may suggest a connection among universities, the life sciences, and the expectations for technology transfer.

The NSF does an annual survey on research and development expenditures. Figure 2.9 categorizes the 40 percent slice of R&D (see Figure 2.7) that includes applied research (shown as "Research Disciplines" constituting 68 percent) and other development (constituting the remaining 32 percent. Life sciences dominates in terms of research disciplines, followed by engineering.

- Research Disciplines (68%)
  - Life Sciences 30%
  - Engineering 16%
  - Mathematics and Computer Sciences 5%
  - Environmental Science 5%
  - Physical Sciences 4%
  - Psychology 3%
  - Social Sciences 3%
  - Other Applied Research 2%
- Other Development (32%)

NSF annual survey of R&D expenditures

Figure 2.9—Life Sciences and Engineering Are Leading Disciplines for Technology Transfer

We should note that absolute percentages of funding may be somewhat misleading because the amount of laboratory equipment or instrumentation needed to conduct social science research may differ significantly from the amount required for biotechnology research. However, this gives our readers some idea of how the disciplines are broken out by funding and by technology transfer expectations.

Measurement Issues in Technology Transfer

The scope of this project did not allow for an independent measure of technology transfer; however, we have done an extensive literature search of what is known on technology transfer. The following discussion summarizes what we know about measures of success in technology transfer. For a further discussion of technology transfer measurement and analysis, see Appendix C.

Whether one believes that technology transfer is successful or is going well likely depends on the individual's role within the technology transfer framework. Figure 2.10 lists the specific roles of the various groups involved in technology transfer and their respective measures of effectiveness. For example, R&D performers, such as inventors, generally are driven by a personal need to champion their invention and to see its usefulness come to fruition, whereas institutions that conduct research may want to license the product of that research and generate revenues from it.

- R&D Performers:
  - Inventors: usefulness of technology
  - Institutions: patents, licenses, revenue
- Entrepreneurs/Venture Capitalists: Growth of companies, wealth creation
- Legislation: Benefits to nation's economic well-being and competitiveness
- Consumers: New or improved products
- Industry: Profit, market share, access to knowledge and expertise, sharing risks, leveraging and complementing R&D portfolios
  - Large firms: generic technologies and early-stage expertise
  - Small firms: products and processes closer to commercialization

Figure 2.10—Measures of Success Depend on One's Role in Technology Transfer

Industry has an interesting perspective on measures of success. Commercial industries obviously want to profit and to gain a greater market share, but they also want access to knowledge and expertise. And large firms have different expectations for technology transfer than do small firms. The research literature suggests that large firms that have an in-house R&D organization generally want more generic technology than expertise, whereas small firms want something that is much closer to end products and commercialization.

Quite a few studies on technology transfer have been done, particularly over the past couple of decades since the original Bayh-Dole and Stevenson-Wydler Acts were passed. In the past 20-plus years, academic researchers have been studying the effects of Bayh-Dole and Stevenson-Wydler, and they generally conclude that these are landmark acts, even if they had to be subsequently amended.

The Interagency Committee on Federal Technology Transfer has identified seven mechanisms for technology transfer, which are listed in Figure 2.11. These mechanisms collectively are a barometer of the vitality of technology transfer. Not all of them are easily measured, however. Table 2.1 lists and defines five general ways in which technology transfer is measured.

The Interagency Committee on Federal Technology Transfer chaired by the Commerce Department has identified these **mechanisms** of technology transfer

1. Licensing
2. Cooperative research and development agreements
3. Technical assistance
4. Reimbursable work for nonfederal partners
5. Use of facilities
6. Exchange programs
7. Collegial interchange, publications, and conferences

Figure 2.11—The Seven Mechanisms for Technology Transfer

Metrics	Definitions
Patents, Licenses, Revenue	Number applied for/granted, basic/applied research, country, affiliation
Manufacturing Innovations	Number of innovations applied for by the Small Business Association
Web Hits to Science Database	Page hits, average time spent on page, number of downloads
Transfer Mechanisms	Number of sign-in visitors, meetings, documents sent/requested, exchanges
Knowledge Spillovers	Estimated statistical relationships of innovation activity

Table 2.1—The Five General Ways of Measuring Technology Transfer

These five general metrics are unlikely to capture the entire picture of technology transfer, but that is to be expected given that technology transfer is understood to be so broad, so long-term, and so indirect in many cases. These general metrics are informative, nonetheless.

Figure 2.12 summarizes some interesting aspects of what past studies on technology transfer have found. For instance, there have been many studies on the effects of universities as a catalyst for innovation to industry. Geographic proximity to universities is important but not for all technologies, just those that are mentioned. So, whereas geographic proximity to universities enhances transfer of medical technology research, interestingly enough, it does not appear to enhance the transfer of information technology. Holding all things constant, geographic proximity to universities matters most to these disciplines that are listed in Figure 2.12.

- Geographic proximity to universities stimulates corporate patent/licensing activity (in particular, drugs, medical tech, optics, nuclear technologies).
- University research generates more innovative activity in nearby small firms than in nearby large firms.
- University research influences firms' marketed innovations more than it influences their patents.
- Firms that conduct R&D in house are more likely to adopt innovative technologies that are developed elsewhere.

Figure 2.12 —A Summary of Some Findings from Previous Academic Study of Technology Transfer

The last item in Figure 2.12 suggests that most firms might like to have an in-house R&D organization, even if it is not productive by in-house standards, in that in-house organizations are best capable of evaluating external technologies, understanding the framework within their firms' business goals, and incorporating them into new or improved products.

Diffusing Technology Innovation and Commercializing Ideas

The commonly accepted goal of technology transfer is successful commercialization. Figure 2.13 displays a curve that is similar to one shown in most marketing textbooks that discuss the challenge of technology diffusion and adoption.

After technology has been transferred and commercialized, the first group to embrace that technology is the *innovators*. The innovators constitute a small portion (just 2.5 percent) of the possible audience for the technology. Innovators tend to use the technology because it is new and interesting, even when there may be little evidence of its effectiveness.

Once the technology's usefulness has been demonstrated, a larger group, known as *early adopters,* is the next to use it. Moore (1991) notes that technology transfer most often never gets beyond this stage--a small fraction of the audience uses the new technology, but a larger portion is wary of change and never embraces the new technology.

Successful marketing encourages the next group, the *early majority,* to try the technology and use it frequently. The encouragement often comes in the form of evidence that appeals to this group: reports of successful use by others, trial runs at similar organizations, and data from vendors to support claims about the technology's benefits.

After the early majority has accepted the technology, the *late majority* will consider joining the group of transferees. That is, when the technology has a proven track record in organizational situations that are similar to the potential adopter's, the late majority will join in.

The last group to use the technology, the *laggards,* is the most resistant to change. Its members feel that they are doing well enough with existing techniques and feel no pressure to change. Laggards are usually convinced to modify their tools and practices only when rules, standards, and regulations are imposed upon them.

In other words, successful commercialization requires defining a market that takes the product beyond the innovators and early adopters.

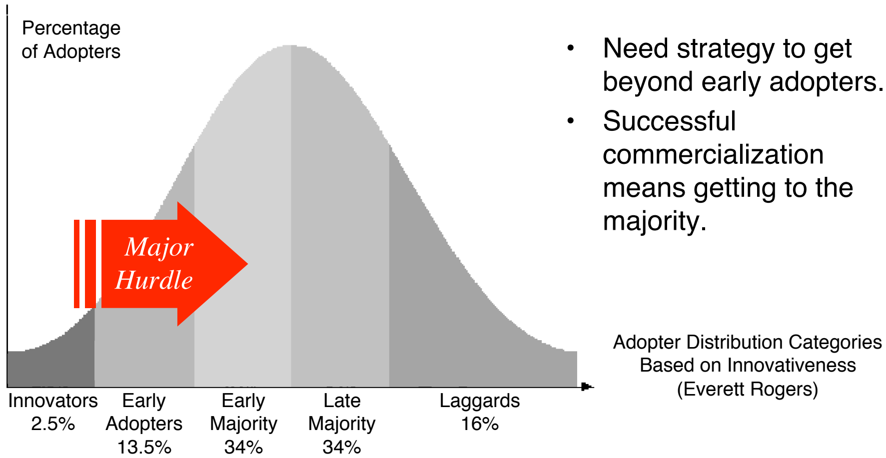

Figure 2.13— Commercialization Depends on Successful Technology Adoption

For example, while it might be possible to find a few customers interested in buying a $2,000 DVD player, unless the firm manufacturing that DVD player identifies a specific market and a plan to reach the majority of consumers within the mark, its new product is unlikely to succeed. Commercialization requires identifying one's market, developing a strategy to reach that market, and having the product adopted by the majority.

The commercialization framework we describe here implies that many factors influence successful commercialization beyond just technology, and a number of those factors are listed in Figure 2.14. Many venture capitalists say that the most important part of commercialization is identifying the market, and they also cite the adage, "There is more money than there are good ideas." For investors, if an entrepreneur can identify a market where there is a profit to be made, they will take care of creating the technology later. For those involved with R&D funding and performing, however, technology transfer starts with the technologies. Thus, the technologies may not be accompanied by the suite of things that need to happen for successful commercialization, including a well-formed business plan.

- Strategy to overcome obstacles and to conquer the mainstream market
- Decision to patent before or after identifying a licensee (patent fees)
- Negotiated licensing terms (up-front payment, equity, exclusivity, royalties)
- Realization that most startups require several stages of investment
- Business plan identifies challengers, competitors, barriers to market entry
- Milestones correspond to proof of technology, management team, market, profitability

Figure 2.14—Factors That Influence Successful Adoption

Universities that are cited for being leaders in technology innovation and entrepreneurship generally are cited for more than the technologies they develop. Leading universities do many other things to help ideas reach their commercial promise, including developing "incubators" or facilitating the interaction among scientists, investors, the business community, and industry.

Lessons from Non-Federal Technology Transfer

This document focuses on technology transfer from federally funded R&D. However, it is useful to investigate how ideas and technology are developed in the absence of federal funds as a way of understanding whether alternative models can help improve the transfer of federally funded R&D.[14]

A look at the history of the transfer of non–federally funded R&D shows that merely having a better technology does not guarantee success. For example, Betamax video technology was generally thought to display a better, clearer picture than VHS, but VHS easily captured the market. The adoption of the "lesser" technology suggests that economic factors are at least as important as quality. Indeed, history is replete with legends of the lone inventor, toiling in a garage to develop a prototype gadget and persevering until an investor recognizes the gadget's value and helps the inventor to succeed and find a market for his or her invention. Similarly, a new idea can linger for years before someone recognizes its application to a particular problem, such as when a chemical compound, ineffective for one ailment, is later recognized as an effective treatment for another.

In many models of successful technology transfer, the venture capital and investment communities play an important role. They recognize that having a good technology is not all it takes. The stakes are high for investors who support risky, early-stage ventures that may not yield immediate returns; the federal government must often invest the preliminary research and development well before the private sector would risk investing in them (e.g., sending a man to the moon or creating a new energy source). Investors often see startup-company development as having distinct stages, each involving different organizations with specific milestones that distinguish one stage from another. These milestones may be activities such as proof of technology, proof of a management team,[15] proof of a market, and proof of profitability.

A good business plan may be the key deciding factor for some technology transfers because investors who must distinguish a good plan from a bad one and decide which to invest in may make the difference between success and failure of a new technology.[16] Beyond describing the new technology, a good business plan must identify challengers, competitors, and barriers to market entry, or demonstrate a sustainable competitive advantage, and identify a strategy for overcoming those challenges. It must also identify specific development and business milestones and market potential. Within the technology diffusion framework described earlier in this chapter, a business plan must also specify how to make the technology attractive to early adopters, to majority markets, and to laggards. Indeed, developing a successful plan to cross from early adopters to mainstream markets may be the most difficult aspect of successful commercialization.[17] Thus, the lesson to be learned is that technology adoption must be accompanied by a well-developed business plan, many aspects of which may be separate from the merits of the technology itself.

Understanding these issues also benefits the technology licensing offices of research institutions. Having greater knowledge of the market potential of technologies aids in the decision whether to patent intellectual property before or after identifying a licensee, or even to suggest the licensee pay patent fees and/or royalties. While some universities generate significant revenues from license royalties, most are trying to break even from patenting costs and try to avoid patenting technologies that may not be licensed.[18] For this reason, most institutions measure the percentage

---

[14] Libicki et al. (2000).

[15] For many venture capitalists, the quality of the management team is as important as the quality of the technology. Given a choice between a mediocre technology and first-rate management team versus a first-rate technology and a mediocre management team, many venture capitalists would select the first-rate team for its ability to execute efficiently and responsively.

[16] Stevens and Burley (1997) quantify the risk associated with technology development, and why much technology transfer fails to yield a commercialized product.

[17] Moore and McKenna (1991).

[18] Association of University Technology Managers (FY2000), and Benowitz (1995).

of patents awarded to gauge this initial return on effort and investments. Other institutions require a senior administrator, such as the provost, to approve each patent application. With patent costs roughly $75,000 and rising, this level of university investment for speculative technologies is similar to "angel" funding and thus benefits from the same entrepreneurial analysis of market, startup management, and business plan potentials as the investor.[19] Enhanced knowledge and information can aid the partnership among the licensing office, entrepreneurs, and early-stage investors by aligning expectations and adding a measure of reality to negotiations of up-front payments, license exclusivity, and royalty terms. Clearing these negotiating hurdles increases the probability that a licensing deal will succeed, a first step for many startup companies.

Beyond initial investments is the need for sustained funding, which often includes several stages of venture capital involvement. Each stage requires additional negotiation and poses the added risk that a venture may fail before successful technology adoption. Investment companies are under increasing pressure from their contributors to maintain positive and short-term returns; the pressures are similar to those from stockholders of public corporations who want immediate returns on their investments. This pressure for immediate results is multiplied if the technology is unproven or the market is speculative. There is a growing wariness among early investors that there will be no one to “grab the baton” as development progresses.[20] This funding gap creates a bottleneck of potentially valuable technologies that are increasingly unable to proceed along the path of commercialization and technology transfer.[21]

One way to address this bottleneck is to reduce investment risk and uncertainty. The risk reduction can be achieved in many ways, some of which have already been noted: better information to define the market, a clear business plan, well-defined milestones, understanding competitors, and a quality management team. Although the commercial sector is usually comfortable with these activities, the academic and research communities may not be. Universities and federal laboratories can encourage commercialization by developing world-class technologies and also by supporting entrepreneurial activities such as those described earlier. To support these efforts, studies of innovation at universities frequently evaluate an institution’s ability to attract and organize industry-sponsored research projects, interface with

[19] A measure being reviewed by the U.S. House of Representatives, Committee on the Judiciary, Subcommittee on Courts, the Internet, and Intellectual Property titled "Strategic Plan and Fee Legislation for the USPTO" would significantly increase the cost of patent prosecution of patent and trademark office fees in the United States.

[20] Private communication, Victor Hwang, chief operating officer, Larta.org (2002).

[21] Price and Sobocinski (2001).

state and regional economic development activities, operate university-affiliated business incubators, and involve the university in early-stage capitalization of spin-off companies.[22]

Other Forms of Technology Transfer

This document focuses on U.S. federally funded research within a framework leading to commercialization, which is commonly associated with technology transfer. Discussions of technology transfer typically are conducted under the assumption that federally funded R&D is transferred to the private sector. The technology transfer process often happens in reverse, however, as technologies move from the private sector to the government. For the government, adopting and using existing commercial technologies avoids duplicating development efforts and saves valuable federal funds. However, it is not easy to identify or to be a "smart buyer" of existing commercial technologies that are applicable to government requirements, given the vast numbers of manufacturers and products and the effort required to evaluate applicability. The sheer numbers of proposals and competing businesses may quickly become unmanageable.

Several Department of Defense agencies enlist the assistance of the venture capital community in reverse transfer. For example, to raise awareness of commercial technologies that may aid homeland security in bioterrorism, the Defense Advanced Research Projects Agency (DARPA) has identified venture firms that specialize in biotechnology. Similarly, the DoD Office of Force Transformation has worked with Tech Coast Angels, a network of individual investors in Southern California, on a "Technology Finder" model that combines early-stage technologies with funding startups after DoD relevance is confirmed. In both cases, venture capitalists' skills in attracting, evaluating, and developing innovative technologies benefit the government. When there is demonstrated government interest in a particular technology, the risk to the investor and to the entrepreneur decreases within a mutually beneficial partnership.

To cite another example, the CIA provides financial support for a venture capital firm, In-Q-Tel, which specializes in finding and developing companies that produce technology of interest to the intelligence community.[23] Although In-Q-Tel is a private-sector firm, it is government created and serves the needs of government.

---

[22] Tornatzky et al., 2002.

[23] From the In-Q-Tel Web site, www.in-q-tel.com/about/history.html: "In 1998, the Director of Central Intelligence (DCI) identified technology as a top strategic priority . . . The leadership of the Directorate of Science and Technology set out a radical plan to create a new venture that would help increase the Agency's access to private sector innovation. In the tradition of the 'skunk works' of the early Cold War era, the DCI called on private sector industry executives to create and launch this new venture. A hybrid between public and private-sector business models, In-Q-Tel was chartered in February 1999 under the leadership of the DCI and the Directorate of Science and Technology and with the support of the U.S. Congress."

Foreign universities and laboratories also have active programs to license intellectual property and transfer technology.[24] Some countries have even tried to base their governance of intellectual property and technology transfer by emulating provisions from the Bayh-Dole Act.[25]

U.S. competitiveness vís a vís foreign countries deserves continued study, particularly to understand those factors that industry weighs before entering partnerships with research firms. Ease of technology transfer is one of many factors large industry weighs before establishing a research partnership with any of the world's research universities and laboratories.

Among the forms of technology transfer not discussed in this report are state and local technology transfer activities (e.g., agricultural transfer programs involving county extension agents or land-grant universities). In addition, some PCAST members mentioned that the "donation" of technologies from the private sector to universities was an increasing form of technology transfer. The military also includes within its definition of outgoing technology transfer the sale of military equipment to allied foreign governments. While graduation of U.S. university students to the U.S. workforce is frequently discussed as being a form of technology transfer, the movement of graduates to foreign countries is not. Although we acknowledge these forms of technology transfer, they are out of the scope of this report.

Is There a Broader Role for the Federal Government in Technology Transfer?

As we mentioned earlier, technology transfer may be very indirect, long-term, and complex. Definitions of technology transfer vary among different stakeholders, even when there is agreement that technology transfer is beneficial and should be improved. Fundamentally, a technology is an idea, practice, or object resulting from research as well as a tool that embodies the technology. The goal of technology transfer is to move a potentially useful idea, practice, or object into an environment where it can improve a product or process in some way, such as by speeding delivery, enhancing quality, reducing cost, or by improving an expected outcome in some way.

Technology transfer involves six elements that combine to form an overall framework: federal funding, R&D, assignment of intellectual property rights, prototyping, product development, and commercialization. The actual technology transfer process used in a given situation uses all of

[24] Mowery (1988).

[25] For a discussion of Canadian technology transfer, see "Public Investments in University Research: Reaping the Benefits," (1999).

these elements, often iteratively. The process is derived from the framework and is based on organization's goals, needs, and culture.

The Bayh-Dole and Stevenson-Wydler Acts are regarded as being examples of successful legislation, but the experiences of technology transfer suggest that improvements may be made. Successful commercialization involves crossing many hurdles, and the federal laws and provisions may only directly affect part of the technology transfer process.

At present, federal policies directly address only the first three stages of the technology transfer framework: federal investment, research and development, and intellectual property. The latter three element—prototyping, product development, and commercialization—are not formally addressed by federal policy, but they are nonetheless critical in assessing the ultimate success of federal-to-private technology transfer. The private-sector experience with technology transfer suggests that good planning, addressing all aspects of transfer through commercialization, can significantly enhance the chances of success.

3. Themes from the PCAST Technology Transfer Forum

Several themes emerged from discussions at the PCAST Technology Transfer Forum on December 12, 2002, as well as from submissions from individuals and organizations involved with technology transfer. The following quoted material represents the views and opinions of those participating in the form; further research is required to discern which remarks may relate to systemic rather than substantive issues, and to separate fact from personal perceptions. Individual perceptions are important, nonetheless, as indicators of where issues may exist and where successful technology transfer may be impacted. The following summaries and excerpted quotations are representative of the main issues and themes that emerged at the forum.

Technology Transfer: Adjusting to the Policy Environment

- Participants generally agreed that improving technology transfer involves a steep learning curve. It has taken decades for organizations to learn how to operate successful transfer programs. Although technology transfer has improved notably since the landmark acts of the 1980s, the partnership between technology developers (particularly universities) and potential industry commercializers is by no means routine or straightforward. The experience of successful organizations suggests that there are payoffs to investing in and building the types of partnerships that facilitate technology transfer.

> "It took the universities about 10-12 years to try to make it work. That meant you had to develop skilled professionals in the business. You also had to develop consistent policies within the universities."
>
> "Technology transfer from national labs or universities to industry is not always easy. Good news. Once we reach an agreement working with universities or national labs, usually those [agreements] come out [to be] very good."

- While acknowledging the learning curve, many forum panelists and attendees believe the technology transfer legislation should not be altered.

> "Bayh-Dole is working. The statistics all show it. You can make it work within the current framework. The mantra of 'if it ain't broke, don't fix it' certainly applies. We are generally asking that one not go into the Bayh-Dole and twiddle with it like the tax code."

- There is a broad perception that the U.S. R&D landscape has changed in the past two decades. The relative share of R&D funded by government is believed to have shifted, altering the balance of basic versus applied research, and a short-term focus versus a long-term one. Interestingly, there is disagreement over whether industry and government funded more in the past than they do now.[26] Much corporate innovation has shifted from in-house development to partnerships with other companies.

> " When universities, particularly research-intensive universities, start getting too involved in the commercialization process, there is that danger of changing the direction of research, of conflict of interest, and of all sorts of, Who are you? What's your proper role?"

General Views of Technology Transfer

- Panelists and attendees noted that technology transfer should be viewed broadly. A framework including federal investment, legislation, and commercialization seemed useful.

> "Focus on the entire technology transfer system holistically, not just one element in isolation, and to consult extensively with federal labs, universities, and industries."

- Many discussed technology transfer within a global context. U.S. competitiveness and an increasingly global economy spurred these comments. Industry partnerships with foreign research institutions was also a recurring point of discussion.

> "We need to better understand the unprecedented global competition for research and innovators. The wealth of nations is changing. While prior centuries were dominated by nations with superior industrial or agricultural capabilities, the Information Age is going to reward new competencies and strengths. Innovative capacity is now clearly the key driver of future national prosperity."

- Successful commercialization requires significantly more than a good idea or new technology. Developing a successful product requires, among other things, effective management, strategy, timing, and marketing. Coordination among many organizations, some with widely varying missions, is a significant challenge.

> "Preconditions to generate successful technology transfer include existing and increasing monetary support for research and development, a solid government patent policy, viable university technology transfer policies, an educated faculty that is aware and interested in technology transfer, availability of discretionary funds for those faculty to protect their intellectual property, and finally, the continued involvement of the inventor in the technology transfer process."
>
> "Industries take risks that the universities or national labs don't take, or don't have to take. Those [risks] are related to development, scale up, and investment in capital. That means if the commercial product is not successful, those investments are wasted. We have to worry about labor relations, to manage working capital, cash flow, and manage inventory. Those are the things that universities and national labs don't have to worry about."

[26] The NSF Survey of Industrial Research and Development (www.nsf.gov/sbe/srs/indus/start.htm) suggests that industry currently funds $200 billion or nearly 60 percent of the total R&D in the United States. The R&D breakdown for industry—73 percent for development, 20 percent for applied research, and 7 percent for basic research—may contribute to perceptions that the government may lead industry in funding R&D because industry has been relying more and more on universities (and some national labs) to do their basic research.

Implementation of Technology Transfer

- Many forum attendees urged that the discussions, particularly of implementation issues, be tailored to specific circumstances. The diversity of the federal laboratories was a repeated example of attendees not wanting generalized discussions. For instance, processes that work for the pharmaceutical industry may not be applicable to agricultural products.

> "Make important discriminating points between agencies, type of funding, and type of subject matter. It's a giant mistake to have a report about technology transfer that compares and pushes together NIH and federal labs. You should just deal with them as different subjects, and have different recommendations for each one."

- Employees at the federal laboratories feel less incentive than their counterparts in universities or industry to contribute to technology transfer. Lack of consulting time, royalties, and equity in startups were among the issues raised. Many joked about the "entrepreneurial leave" program — to be an entrepreneur, they must *leave*. There are also perceived differences at government-operated versus contractor-operated federal laboratories. These perceptions may hinder technology transfer since involvement of the inventor, particularly early in the development phase, is widely considered to be critical to the successful commercialization of new ideas.

> "Conflict of interest, and the [inspector generals (IGs)] come to the GOCOs as well. And the last thing you want to do is get skewered on the front pages of The Washington Post or something like that. In fact, what throttles even consulting at these laboratories are notions of conflict of interest. And the reason [is] that people can't own equity; even though our laboratory owns equity in companies, individuals do not, nor can they. So therefore, if it's a federal laboratory, GOCO or GOGO or anything else that you might be able to think of, the conflict of interest issue is one that is very, very real, and is an ultimate wet blanket on many, many of these things. "

- The implementation of technology transfer is not uniform. Technology licensing offices at research universities and federal laboratories pursue varying approaches to deciding whether to patent a technology and how to structure licensing or royalty agreements. Some of these differences follow from inherent differences in the research--for example, divergent development, investment, and returns from new pharmaceutical products versus agricultural commodities. Other differences stem from diversity across federal laboratories and university research programs. Another important change is the increase in interdisciplinary and jointly sponsored research. Such arrangements can create confusion when ownership of intellectual property is not clear. For example, a federal employee may have a joint appointment at a university, working on research jointly sponsored by the federal government and industry.

> "Complexity is the enemy of execution. To the extent that you have problems in the implementation of technology transfer, most of them are either a function of misalignment between agency mission, or people who don't understand what they are doing because the laws and regulations are too complicated."

> "Misapplication of Bayh-Dole may adversely affect innovation and technology transfer, at least in some technologies, and may lead to conflict between universities and industry. Companies, who sponsor research with your own private dollars, have the expectation of being able to use and commercialize those research results productively."

- Resources early in the technology transfer process are sought by all parties. For inventors, resources are needed to develop the technology. Investors also need resources to explore and develop the business potential of new ideas. Universities must weigh potential benefits against the initiation of an expensive and time-consuming patent application process. If a patent is obtained, licensing terms that require up-front cash payments may also present a hurdle.

> "Venture capital seems to have dried up. We do preferentially license to small businesses. They are risk takers. They need that capital influx typically to move things forward. And that has had an impact this past year."

Steps for the Future

- Many forum participants recommended training tools and education courses on technology transfer including explanations of the use of various technology transfer mechanisms.
- Homeland security issues were raised by some forum participants, in the context of planning for increased research and development and moving technologies into public use.

> "The biggest challenge of the federal government today is how do you do technology transfer in a new cabinet level department? What kind of biodefense industry or counterterrorism measure industry do we want or deserve in the United States?"
>
> "The federal laboratories are very good at building ones and twos and tens of a kind. They are not good at building thousands of things."

- Some participants suggested examining how technology transfer is accomplished in other countries. In the U.K., for example, the R&D departments of some companies are brought within universities and nurtured by them.
- Many agreed that technology transfer, and the many issues it raises, require further research to develop and improve technology transfer metrics. While participants were encouraged to define successful technology transfer in terms that were most useful to them, this also prevented direct or specific comparisons.

Summary

PCAST Technology Transfer Forum participants at the represented a wide range of perspectives, including those of university technology-transfer officers, industry leaders, and federal R&D managers and lab personnel. There was general agreement that technology transfer processes and "best practices" vary widely in different contexts. The input from the forum provided important, albeit anecdotal, evidence that will help further understanding of which technology transfer practices work best and in which contexts.

Due to time constraints in planning the forum, not all perspectives on technology transfer were evenly represented. For example, few researchers and scholars from the disciplines that study technology transfer were able to attend. A deeper study of technology transfer processes would require greater participation from *all* stakeholders. More comprehensive stakeholder input will also help ground more rigorous analysis of technology transfer and a more empirically based approach to understanding technology transfer best practices.

Appendix A. Conference Agenda

PCAST Technology Transfer Forum
Thursday, December 12, 2002

RAND Washington, D.C., Office
1200 South Hayes Street, Arlington, VA
Room 4204

Agenda

0900-0915	Welcome and Introductions	Wayne Clough, Georgia Tech Richard Russell, Office of Science and Technology Policy
0915 - 1000	Overview of Technology Transfer	Mark Wang, RAND
1000 – 1015	Break	
1015 – 1200	Technology Transfer Roundtable	Bruce Mehlman, U.S. Department of Commerce (moderator) Panelists: David Beier, Hogan and Hartson Richard Brenner, Agricultural Research Service Lita Nelsen, MIT Kate Phillips, Council on Governmental Relations Frank Pita, Semiconductor Research Corp. Al Romig, Sandia National Labs Juliana Shei, GE
1200 – 1300	Lunch	
1300 – 1600	Open Forum Preregistered speakers will be allowed 5 minutes. Walk-in speakers will follow.	
1600	Adjourn	

Appendix B. Summary of Technology Transfer Legislation

This appendix provides a compendium of relevant technology transfer legislation, listed in chronological order. Table B.1 relates the legislation to federally funded R&D.

The Morrill Land-Grant Act of 1862

- Promoted education and innovation in science and technology by forming a system of publicly supported research universities.

National Aeronautics and Space Act of 1958 (PL 85-568)

- Granted NASA broad discretion in the performance of its functions.
- Authorized the NASA Administrator to enter into and perform such contracts, leases, cooperative agreements, or other transactions as may be necessary in the conduct of its work and on such terms as it may deem appropriate, with any agency or instrumentality of the United States, or with any State, Territory, or possession, or with any political subdivision thereof, or with any person, firm, association, corporation, or educational institution.
- Permitted the Administrator to engage in international cooperative programs pursuant to NASA's mission.

The Freedom of Information Act (1966) (PL 104-231) [5 USC 552]

- Provided a vehicle to inform the public about federal government activities.
- Gave citizens the right to request agency records and have them available promptly.

Stevenson-Wydler Technology Innovation Act of 1980 (PL 96-480) [15 USC 3701–3714]

- Focused on dissemination of information.
- Required Federal Laboratories to take an active role in technical cooperation.
- Established Offices of Research and Technology Application at major federal laboratories.
- Established the Center for the Utilization of Federal Technology (in the National Technical Information Service).

Bayh-Dole Act of 1980 (PL 96-517)

- Permitted universities, not-for-profits, and small businesses to obtain title to inventions developed with governmental support.
- Provided early on intellectual property rights protection of invention descriptions from public dissemination and Freedom of Information Act (FOIA).
- Allowed government-owned, government-operated (GOGO) laboratories to grant exclusive licenses to patents.

Small Business Innovation Development Act of 1982 (PL 97-219)

- Required agencies to provide special funds for small-business R&D connected to the agencies' missions.
- Established the Small Business Innovation Research Program (SBIR).

Cooperative Research Act of 1984 (PL 98-462)

- Eliminated the treble-damage aspect of antitrust concerns of companies wishing to pool research resources and engage in joint precompetitive R&D.
- Resulted in consortia, e.g., the Semiconductor Research Corporation (SRC) and Microelectronics and Computer Technology Corporation (MCC), among others.

Trademark Clarification Act of 1984 (PL 98-620)

- Permitted decisions to be made at the laboratory level in government-owned, contractor-operated (GOCO) laboratories as to awarding licenses for patents.
- Permitted contractors to receive patent royalties for use in R&D or awards, or for education.
- Permitted private companies, regardless of size, to obtain exclusive licenses.
- Permitted laboratories run by universities and nonprofit institutions to retain title to inventions, within limitations.

Japanese Technical Literature Act of 1986 (PL 99-382)

- Improved the availability of Japanese science and engineering literature in the United States.

Federal Technology Transfer Act of 1986 (PL 99-502)

- Made technology transfer a responsibility of all federal laboratory scientists and engineers.
- Mandated that technology transfer responsibility be considered in employee performance evaluations.
- Established a principle of royalty sharing for federal inventors (15 percent minimum) and set up a reward system for other innovators.
- Legislated a charter for the Federal Laboratory Consortium for Technology Transfer and provided a funding mechanism for that organization to carry out its work.
- Provided specific requirements, incentives and authorities for the Federal Laboratories.
- Empowered each agency to give the director of GOCO laboratories authority to enter into cooperative R&D agreements and negotiate licensing agreements with streamlined headquarters review.
- Allowed laboratories to make advance agreements with large and small companies on title and license to inventions resulting from Cooperative R&D Agreements (CRADAs) with government laboratories.
- Allowed directors of GOGO laboratories to negotiate licensing agreements for inventions made at their laboratories.
- Provided for exchanging GOGO laboratory personnel, services, and equipment with their research partners.
- Made it possible to grant and waive rights to GOGO laboratory inventions and intellectual property.
- Allowed current and former federal employees to participate in commercial development, to the extent that there is no conflict of interest.

Malcolm Baldrige National Quality Improvement Act of 1987 (PL 100-107)

- Established categories and criteria for the Malcolm Baldrige National Industry Award.

Executive Orders 12591 and 12618 (1987): Facilitating Access to Science and Technology

- Promoted the commercialization of science and technology.

Omnibus Trade and Competitiveness Act of 1988 (PL 100-148)

- Placed emphasis on the need for public/private cooperation in assuring full use of results and resources.
- Established centers for transferring manufacturing technology.

- Established Industrial Extension Services within states and an information clearinghouse on successful state and local technology programs.
- Changed the name of the National Bureau of Standards to the National Institute of Standards and Technology and broadened its technology transfer role.
- Extended royalty payment requirements to nongovernment employees of federal laboratories.
- Authorized Training Technology Transfer centers administered by the Department of Education.

National Institute of Standards and Technology Authorization Act for FY 1989 (PL 100-519)

- Established a Technology Administration within the Department of Commerce.
- Permitted contractual consideration for rights to intellectual property, other than patents, in cooperative research and development agreements.
- Included software development contributors eligible for awards.
- Clarified the rights of guest worker inventors regarding royalties.

Water Resources Development Act of 1988 (PL 100-676)

- Authorized Army Corps of Engineers laboratories and research centers to enter into cooperative research and development agreements.
- Allowed the Corps to fund up to 50 percent of the cost of the cooperative project.

National Competitiveness Technology Transfer Act of 1989 (PL 101-189)

- Granted GOCO federal laboratories the opportunity to enter into CRADAs and other activities with universities and private industry, under essentially the same terms as stated under the Federal Technology Transfer Act of 1986.
- Allowed information and innovations, brought into and created through cooperative agreements, to be protected from disclosure.
- Provided a technology transfer mission for the nuclear weapons laboratories.

Defense Authorization Act for FY 1991 (PL 101-510)

- Established model programs for national defense laboratories to demonstrate successful relationships among federal government, state and local governments, and small businesses.

- Provided for a federal laboratory to enter into a contract or memorandum of understanding with a partnership intermediary to perform services related to cooperative or joint activities with small businesses.
- Provided for the development and implementation of a National Defense Manufacturing Technology Plan.

Intermodal Surface Transportation Efficiency Act of 1991 (PL 102-240)

- Authorized the Department of Transportation to provide not more than 50 percent of the cost of CRADAs for highway research and development.
- Encouraged innovative solutions to highway problems and stimulated the marketing of new technologies on a cost-shared basis of more than 50 percent if there is substantial public interest or benefit.

American Technology Preeminence Act of 1991 (PL 102-245)

- Extended Federal Laboratory Consortium (FLC) mandate, removed FLC responsibility for conducting a grant program, and required the inclusion of the results of an independent annual audit in the FLC Annual Report to Congress and the President.
- Included intellectual property as potential contributions under CRADAs.
- Required the Secretary of Commerce to report on the advisability of authoring a new form of CRADA that permits federal contributions of funds.
- Allowed laboratory directors to give excess equipment to educational institutions and nonprofit organizations as a gift.

Small Business Technology Transfer (STTR) Act of 1992 (PL 102-564)

- Established a three-year pilot program—Small Business Technology Transfer (STTR)—at the Department of Defense (DoD), Department of Energy (DOE), Department of Health and Human Services (HHS), the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF).
- Directed the Small Business Administration (SBA) to oversee and coordinate the implementation of the STTR Program.
- Designed the STTR to be similar to the Small Business Innovation Research (SBIR) program.
- Required each of the five agencies listed above to fund cooperative R&D projects involving a small company and a researcher at a university, federally funded research and development center, or nonprofit research center.

National Department of Defense Authorization Act for 1993 (PL 102-25)

- Facilitated and encouraged technology transfer to small businesses.

National Defense Authorization Act for Fiscal Year 1993 (PL 102-484)

- Established the DoD Office of Technology Transition.
- Extended the streamlining of small-business technology transfer procedures for non-federal laboratory contractors.
- Directed the DOE to issue guidelines to facilitate technology transfer to small businesses.
- Extended the potential for CRADAs to some DoD-funded Federally Funded Research and Development Centers (FFRDCs) not owned by the government.

National Defense Authorization Act for Fiscal Year 1994 (PL 103-160)

- Broadened the definition of a laboratory to include the weapons production facilities of the DOE.

National Technology Transfer and Advancement Act of 1995 (PL 104-113)

- Gave CRADA partners sufficient intellectual property rights to justify prompt commercialization of inventions resulting from a CRADA.
- Authorized CRADA partners the right to an exclusive or nonexclusive license resulting from a CRADA.

Technology Transfer Commercialization Act of 2000 (PL 106-404)

- Improved the ability of federal agencies to license federally owned inventions by reforming technology training authorities under the Bayh-Dole Act.
- Permitted laboratories to bring already existing government inventions into a CRADA.

Table B.1

PERFORMERS of FEDERAL R&D	B-D: USBPPA	B-D: TCA	B-D: EO	S-W	SA	AEA/FNERA	DOD	HHS	NASA	DOE	NSF	USDA	DOC	Other	TOTAL 2002 (estimated obligations in 1,000's)
TOTAL Conduct of Federal R&D by All Performers							34,235,264	23,815,897	7,259,400	6,321,757	3,017,080	1,805,885	1,111,554	3,078,614	80,645,451
Federal laboratory															
Operated by USG (intramural)				X	X	X	7,898,700	4,133,700	1,841,900	510,100	20,300	1,268,200	911,300	1,701,000	18,285,200
Operated by university/college (i.e., GOCO FFRDC)		X					272,400	67,000	1,199,700	2,481,800	167,600	0	100	25,200	4,213,800
Operated by non-profit (i.e., GOCO FFRDC)		X					400,500	42,500	5,100	549,800	5,300	0	100	115,600	1,118,900
Operated by industrial firm (i.e., GOCO FFRDC)		X					212,100	270,400	200	895,000	0	0	0	19,700	1,397,400
Universities & Colleges	X						1,615,300	13,528,600	845,100	643,600	2,506,200	500,900	109,100	450,100	20,198,900
Non-profit/non-educational	X						258,000	3,806,900	444,400	49,600	163,900	16,300	10,000	341,800	5,090,900
Industry/business[1]							23,473,800	1,710,300	2,900,700	1,078,800	130,300	14,100	74,200	432,800	29,815,000
Large business (est.)			X				*19,436,306*	*371,135*	*2,201,631*	*569,606*	*16,418*	*592*	*41,849*	*319,437*	*22,956,975*
Small business (est.)	X						*4,037,494*	*1,339,165*	*699,069*	*509,194*	*113,882*	*13,508*	*32,351*	*113,363*	*6,858,025*
Other															
State/Local U.S. government				X			2,900	167,100	8,100	11,500	10,200	3,000	6,500	60,000	269,300
Foreign government	na						101,700	89,400	41,300	1,500	13,300	3,400	200	5,300	256,100
Bayh-Dole Act (B-D) (35 USC 200 et. seq.)	**77%**						26,232,100	19,425,700	5,395,200	5,698,600	2,973,300	531,300	193,500	1,385,200	61,834,900
University and Small Business Patent Procedures Act (USBPPA)	***40%***						*5,910,794*	*18,674,665*	*1,988,569*	*1,202,394*	*2,783,982*	*530,708*	*151,451*	*905,263*	*32,147,825*
Trademark Clarification Act (TCA) [2]	***8%***						*885,000*	*379,900*	*1,205,000*	*3,926,600*	*172,900*	*0*	*200*	*160,500*	*6,730,100*
E.O. 12591 (EO)	***28%***						*19,436,306*	*371,135*	*2,201,631*	*569,606*	*16,418*	*592*	*41,849*	*319,437*	*22,956,975*
Stevenson-Wydler (S-W) (15 USC 3700, et. seq.)[3]	**20%**						7,901,600	4,300,800	8,100	11,500	30,500	1,271,200	917,800	1,761,000	16,202,500
Space Act (SA) (42 USC 2457)[4]	**2%**						na	na	1,841,900	na	na	na	na	na	1,841,900
Atomic Energy Act (AECA) (42 USC 2182) and Federal Nonnuclear Energy Research Act (FNERA) (42 USC 5908)[5]	**1%**						na	na	na	510,100	na	na	na	na	510,100
Basic Research	**Too early for TT**						1,363,205	12,969,005	2,548,050	2,339,169	2,799,076	848,751	53,351	478,684	23,399,291
Major Systems Development	**Off limits for TT**						25,246,972	0	0	0	0	0	0	0	25,246,972
Applied Research and Non-Major Systems Development	**Prime Candidates for TT**						7,625,087	10,846,892	4,711,350	3,982,588	218,004	957,134	1,058,203	2,599,930	**31,999,188**
Life Sciences	*30%*						*406,149*	*7,718,402*	*150,301*	*44,909*	*15,911*	*600,023*	*188,969*	*542,042*	*9,666,706*
Engineering	*16%*						*2,010,441*	*236,673*	*1,258,802*	*857,352*	*125,367*	*35,361*	*145,558*	*337,135*	*5,006,689*
Mathematics and computer sciences	*5%*						*699,457*	*94,600*	*45,310*	*711,931*	*19,970*	*10,745*	*76,547*	*31,782*	*1,690,342*
Environmental Science	*5%*						*128,729*	*238,543*	*308,224*	*56,388*	*2,009*	*6,987*	*384,324*	*463,383*	*1,588,587*
Physical Sciences	*4%*						*161,156*	*375,403*	*90,316*	*485,377*	*23,688*	*37,861*	*82,867*	*52,575*	*1,309,253*
Psychology	*3%*						*40,322*	*899,644*	*13,259*	*0*	*25*	*275*	*0*	*76,920*	*1,030,445*
Social sciences	*3%*						*26,782*	*260,755*	*0*	*0*	*15,160*	*113,252*	*27,767*	*472,257*	*915,973*
Other Applied Research n.e.c.	*2%*						*183,988*	*342,459*	*6,713*	*9,100*	*15,874*	*2,395*	*60,848*	*98,245*	*719,622*
Development, Non-Major Systems	*31%*						*3,968,064*	*680,413*	*2,838,425*	*1,817,531*	*0*	*150,235*	*91,323*	*525,580*	*10,071,571*

All amounts are from "Federal Funds for Research and Development: Fiscal Years 2000, 2001, and 2002, Volume 50 (NSF 02-321).

[1] The percent of each agency's R&D contracts that were awarded to Small Businesses were determined using RaDiUS. Since the government-wide percent is 25%, this amount was used to determine "Other."

[2] In implementing the TCA requirements, DOE has effectively adopted, via the provisions of FFRDC M&O contracts, the language of Stevenson-Wydler.

[3] The technology transfer activities of all federal intraumral R&D is governed by Stevenson-Wydler, while their patenting and licensing activities are governed by Bayh-Dole. Stevenson-Wydler was amended by the Federal Technology Transfer Act of 1986 which allowed lbaoratories to license their inventions, and after sharing 15% with the employee inventor, keep all the remaining royalities.

[4] The Space Act governs the intramural technology transfer activities of NASA only.

[5] The Atomic Energy Act and the Federal Nonnuclear Energy Research Act govern the intramural technology transfer activities of DOE only.

Appendix C. Measuring Technology Transfer

Because technology consists of knowledge that may be embedded in complex processes, it is difficult to quantify and assess the transfer of that knowledge. Systematic study of technology transfer is still a fairly youthful field, having come into prominence over the past two decades, partly in response to the Bayh-Dole and Stevenson-Wydler Acts of 1980. This appendix focuses on the current state of metrics for analyzing federal technology transfer activities.

In this appendix, we address three questions:

- What are the main mechanisms of technology transfer?
- What constitutes a successful transfer?
- What metrics have been used to measure transfer and evaluate "success"?

Measurement and Analysis Issues

Successful measurement and analysis must begin with clear concepts and definitions that answer important questions, such as what "technology transfer" means, and which activities and processes are included and excluded. An interagency working group of the Interagency Committee on Federal Technology Transfer (chaired by the Department of Commerce) has provided useful answers by identifying the most important mechanisms of federal technology transfer:

1. Licensing

   Legislation enacted over the past two decades to streamline the process of patenting and licensing by universities, national laboratories, and federal agencies of the results of federally funded research has greatly increased the volume of patent applications. The motivation for seeking to increase patent applications includes the revenue stream generated from licensing the patent and the protection afforded by a patent, attracting companies, investors, and entrepreneurs to license the patent for commercial application.

   New technology-based companies established to commercialize technologies developed by federally funded research and development often involve the professors and university students who developed the technology. These researchers bring with them in-depth knowledge and a level of effort borne out of their personal stake in the success of the technology transfer.

2. Cooperative activities

   Cooperative activities between universities or federal laboratories and the private sector are facilitated through legal mechanisms. These mechanisms include CRADAs and Space Act agreements, for example.

3. Technical assistance

   Research personnel and scientists at universities or federal laboratories provide paid or unpaid technology consulting to commercial firms.

4. Reimbursable work for nonfederal partners

5. Use of facilities

6. Exchange programs

   The exchange of personnel in either direction between research organizations and commercial enterprises can develop informal channels of communication that enable successful transfer of technology. Professors spending their sabbaticals in a company laboratory are exposed to technical challenges that they can bring back to their laboratories while also contributing knowledge toward solving more immediate problems. The knowledge they bring back to their laboratories will provide a broader context for their work and their training of students, who will, in turn, bring knowledge with them as they join the workforce. Student internships at companies serve a similar purpose.

   Companies may also identify specific research groups whose work is of interest to them and send technical personnel to work in those laboratories through formal collaborations and joint development projects.

7. Collegial interchange, publications, and conferences

   The publication and presentation of research is another major pathway by which information about methods, processes, and discoveries is disseminated. Informal conversations during conferences may likewise foster the person-to-person connections that lead to technology transfer.

   The education and training of students may result in transfers of knowledge from university research into the private sector. Students contribute to technology through their research activities at their universities, followed by their moving into the workforce, whether into an established company, into government, or by starting a company based on their graduate work. The national laboratories and federal agencies participate in this form of technology transfer as well, although to a lesser extent, given the nature of their primary missions.

Some technology transfers may involve only a single event, while others may span two or more events. For example, a collegial interchange may lead scientists from a business firm and a laboratory to design a cooperative R&D project resulting in a CRADA. From that experience, the firm might license some intellectual property from the laboratory. Once a relationship is developed between a business firm and a laboratory, that relationship may come to encompass many technology transfer mechanisms.

Defining these mechanisms is the first step in understanding how to gauge the success of technology transfer. Next, the goals of the transfer must be articulated clearly, so that measurement can address them. Although defining a vision of success sounds straightforward, in fact there may be serious difficulties in defining a measure of what constitutes success. For example, many laboratory technology transfer officials believe that the completed hand-off of a technology constitutes success.[27] After all, once the transfer is made to a commercial firm, there are many non-technology factors over which the transferor has limited influence, and these factors affect whether the transferor's contribution will have an economic impact. In addition, defining success by the number of hand-offs simplifies the measurement task and directly indicates the transferor's skill at making transfers.

However, this limited definition is inadequate for addressing some policy questions. There is policy interest in knowing whether the universities and federal laboratories are contributing to the nation's economic well-being and competitiveness. Knowing this requires systems that measure the economic impact of technology transfers. Such impacts might be measured in the dollar amounts of new sales, payrolls, and similar outcomes at the societal level. But in many cases the impact will be felt mostly at the business-firm level and may take the form of cost reduction or cost avoidance, concepts that are more subjective and more difficult to measure.

Moreover, many federally funded R&D activities involve universities and federal laboratories, where the culture and organizational goals differ from those in the commercial sector. Consequently, industry has no single definition of successful interaction with universities and federal laboratories. Some would consider new or improved products and short-term profits to be the bottom line, judging success or failure on that basis. However, a survey of Industrial Research Institute members indicated that a majority of chief technical officers believe the most important payoffs from these interactions occur in the form of access to knowledge and expertise, leveraging R&D, sharing risks, and complementary R&D portfolios.[28] These benefits

[27] Robb (1991).
[28] Roessner (1993), p. 8.

have economic impacts, but the impacts emerge only in the long-term. Some analysts feel that industry views of success may be influenced by company size. Large firms with internal product development and R&D tend to seek more generic technologies and expertise in earlier stages of maturity, whereas smaller firms more often seek help with products and processes at a point closer to commercialization.[29]

After the parties agree on goals, the challenge of measurement becomes constructing metrics that capture the appropriate characteristics of the technology, the actors, and the transfer to determine if the goals are being met. Measurement activities involve collecting data about actual processes and efforts. For example, if one goal of transfer is to generate a profusion of patents and licenses, then published data on patents and licenses are a source of information about the output from the processes and activities. Sidebar C.1 illustrates how several different measures of technology transfer are used to assess the impact of the Bayh-Dole Act on innovation. Special surveys and case studies of firms, laboratories, and universities are other sources of information about inputs, processes, and outputs. Sometimes a measure is very particular to the goal or area of development. For example, one innovative approach examines the Word Wide Web as a conduit of scientific knowledge to biotechnology developers. Another features a large database of strategic organizational alliances among universities, laboratories, and industrial firms. Statistical analysis of these varied data shows promise in understanding the so-called "valley of death" in technology transfer: the gap in funding, for example, between the time a paper is published and the decision to invest in the technology described in the paper.

[29] Kassicieh and Radosevich (1994).

Sidebar C.1—Assessing the Impact of Bayh-Dole on Innovation

Analysts at the *Economist* magazine measured the impact of Bayh-Dole on American innovation.[30] They noted that before Bayh-Dole "inventions and discoveries made in American universities, teaching hospitals, national laboratories and non-profit institutions sat in warehouses gathering dust." The U.S. government owned 28,000 patents in 1980, but only 5 percent had been licensed to industry. At the same time, the federal government was providing 60 percent of the funding for academic research. However, since Bayh-Dole was passed, there has been a tenfold increase in patents generated at universities, and the universities have created 2,200 firms to commercialize research done in their laboratories. Rather than absorbing funds, universities have begun generating funds for the American economy, creating 260,000 jobs and pumping $40 billion annually into the economy.

The Metrics and Their Uses

Despite the challenges in measuring and assessing technology transfer, it is possible to develop useful metrics of technology transfer. Practitioners and scholars of technology transfer have developed diverse metrics, including:

- Science, technology, engineering, and mathematics graduates taking jobs in the technology sector
- Patents
- Manufacturing innovations
- Web hits to a science database
- Innovation networks
- Transfer mechanisms
- Knowledge spillovers.[31]

Table C.1 describes the following seven characteristics of each of these metrics

- **Definition.** How is this metric defined in actual use? Each metric corresponds to at least several operational definitions.
- **Application field.** For which fields of science or technology has this metric been collected?

[30] "Innovation's Golden Goose," (2002).

[31] Another possible metric of interest is cost savings: the savings in having someone else do the research and transfer it. For example, cost savings have been documented for a major development at DuPont--the replacement of Freon (Kanter, Kao, and Wiersema1997, pp. 84-85).

- **Directly or indirectly measured.** Is the transfer directly observed in data or a case study, or is it inferred from statistical estimation of relationships between innovation activities of transferors and transferees?
- **Data source.** Is this measure documented in publicly available data, special surveys, or case studies?
- **Strengths.** What are the main advantages of this metric, compared with others?
- **Weaknesses.** What are the main drawbacks?
- **Key citations.** What papers or books have developed this metric or collected data on it?

Table C.2 summarizes how the same seven metrics have been used to describe or understand the elements of technology transfer. The table summarizes the following five aspects of the use of the metrics:

- **Application field.** To which fields of science or technology has this metric been applied?
- **Focus on transferor, transferee, or process?** Which category of actor in the process gets the researcher's attention, or is the attention on the process itself?
- **What is the purpose or hypothesis for the analysis?** What question—academic or practical—motivates the research?
- **Principal findings.** What research results have emerged to advance the science or inform the actions of universities, laboratories, firms, or government?
- **Key citations.** What papers or books present or summarize these analyses?

Table C.1: Definitions and Characteristics of Technology Transfer Metrics

Metrics	Definition	Application Field	Directly or Indirectly Measured	Data Source	Strengths	Weaknesses	Key Citations
STEM Graduates Taking Jobs in Tech Sector	Number of degree recipients beginning private sector technical employment	All fields	Directly measured	National Science Foundation	–A measure of human capital inflows to industry –Measured at all degree levels –Available for major fields of study and industrial sector –Available annually	–Does not indicate quality of education	National Science Board (2002),
Patents	number applied for/granted; by field of S&T; whether basic or applied; by country and institutional affiliation of applicant	All Fields	Directly measured	United States Patent and Trade Office	–Data characteristics are known through extensive analysis –Various prepared data files available –Available for many countries	–Not the equivalent of a direct measure of innovative output –Many inventions are not patented, probably increasingly in some industries	Acs and Audretsch (1989), Griliches (1990), Hall et al (2001)
Manufacturing Innovations	Number of innovations recorded by the SBA in 1982 from leading technology, engineering, and trade journals	Separate manufacturing industries	Directly measured	Publicly available	Includes inventions not patented but still introduced into the market and excludes those that were patented but yet never appeared in the market	Available only for 1982	Acs and Audretsch (1988, 1990)
Innovation Networks	Databases of panel data on strategic partnerships (joint ventures) among companies, universities and laboratories; on patents and patent citations; and on company financial performance. 1985-1999.	All fields	Directly measured	Justice Department administrative records on strategic partnership formation; public patent data, and publically available	–A process measure that characterizes strategic alliances –Includes all strategic partnerships registered with the Federal government –Merges data on nature and technical area of partnership with data from other sources for each of the partners	–	Vonortas (2001)
Web hits to Science Databases	Information accessed from databases, e.g., number of "hits", average time spent on page, # of downloads	Genomics (so far)	Directly measured	analysis of server logs of genomic sequencing data from the three largest public global biodatabases	–A direct measure of transfer activity –A "pull" measure –Very large number of transactionsidentification of type of transferee –Identification of detailed application field of information	–Applicable only to transfers occurring over the web –Requires high volume of transfers for statistical analysis –May require web source permission to acquire data	Enriquez and Martinez (2002)
Transfer Mechanisms	# sign-in visitors from the university; # meetings together; # documents sent from a university (push); # university documents requested by firm staff (pull); # seminars attended; # personnel exchanges/transfers; time required to complete agreements; etc.	All Fields	Directly measured	Special survey or case study	Documents detailed transfer opportunities	–Hard to define a project's start, end, and boundaries—once adopted by the firm or not until commercialized? –Hard to deal with the counterfactual—Would the transferee have developed the technology even without the transfer? –Universities and firms can be reluctant to provide data –Experiences tend to be localized and hard to generalize	Melkers and Cozzens (1997), Feller (1988), Janis (1997), Bennett (1997)
Knowledge Spillovers	Estimated statistical relationship between innovation activity at universities, labs, or other firms, on the one hand, and innovation activity, new technology, or economic effects at transferee firms, on the other hand	All Fields	Indirectly estimated	–Published patent data –Published federal business statistics reported by industry and geography –Special surveys of firms	Requires no direct measure of transfer	–Requires econometric expertise to estimate inferred transfer activity –Does not identify mechanisms of tech transfer	Mansfield (1980), Jaffe (1986), Zoltan et.al. (1994)

Table C.2: Analytical Uses of Technology Transfer Metrics

Metrics	Application Field	Focus	Purposes	Principal Findings	Key Citations
STEM Graduates Taking Jobs in Tech Sector	Few so far	Process	To study the relationship between the number of new STEM employees, and technology adoption and use in the private sector	These personnel flows are yet to be directly examined as a factor in thechnology tranfer	–
Patents	Many	Both transferor and transferee	To study the relationship between patent activity in universities and Federal labs, on the one hand, and technology adoption and use in the private sector, on the other hand.	–Strong positive correlation between firms' R&D expenditures and their patents –Strong positive correlation between patent activity in nearby universities and measures of firms' R&D effectiveness –Citation-weighted measures of patents are more highly correlated with firms' market value than unweighted measures	Griliches (1990), Hall et.al. (2000)
Manufacturing Innovations	Manufacturing	Transferee	To improve on patents as a measure of output of firm's S&T activities	–Impact of university spillovers is greater on firms' innovations than on firms' patents –Influence of geographic proximity of universities is much stronger on firms' innovations than on firms' patents	Acs, et.al.(1992)
Innovation Networks	All Fields	Process	To study the efficacy of different forms of strategic partenerships in inducing technology transfer and innovation	Analysis is just underway, using formal network models	Vonortas (2001)
Web hits to Science Databases	Genomics (so far)	Transferee	To describe amount of data transferred, by characteristics of firms and labs, by country, and by application field	–Nucleotide data to be transferred is growing super exponentially –The U.S.database is increasingly dominant in both data and access, compared to European and Japanese databases –Half of world database access comes from U.S. organizations –98% of downloads from the Japanese database were from Japan, but foreigners account for more than half the downloads from U.S. and Europe –The top three accessing countries accounted for 3/4 of total usage –The most active .edu user accounted for 1/4 of all U.S. .edu downloads. The top 10 accounted for 92%. –U.S. .com use was almost as concentrated, 17% and 85% respectively. –.com downloads were very rare in Japan compared with 48% in U.S. –Humans grew from 0% of genome module downloads to 85% between 1998 and 2001	Enriquez and Martinez (2002)
Transfer Mechanisms	All Fields	Process	–To evaluate tech transfer experiences –To identify best practice mechanisms for adoption by universities and firms	Findings are for specific partnerships and states	Bozeman (1997), Melkers and Cozzens (1997)
Knowledge Spillovers	All Fields	Both transferor and transferee	–To identify conditions favorable and unfavorable to transfer –To estimate the effects of transferor S&T activity on transferee activity and economic outcomes	–Nearby university research has substantial effect on corporate patent activity in drugs, medical technology, electronics, optics, and nuclear technology, and less in other fields –spillovers from universities are a more important input for generating innovative activity in small firms than in large ones. –Adoption of innovations from outside the firm occurs more rapidly in firms that themselves spend more on R&D. Hence, firms may invest in R&D even when it produces little innovation directly, in order to be able to assimilate and exploit innovations from outside. –Firms whose research is in application areas where there is much research by other firms have, on average, more patents per dollar of R&D and a higher return to R&D in terms of accounting profits or market value. Profitability of low R&D firms is lower in this environment than otherwise. –Number of manufacturing innovations yielded per dollar of in-state university research is highest in mechanical industries and lowest in chemical industries. Yield of manufacturing innovation per university patent is also highest in electronics and lowest in chemicals.	Link and Rees (1990), Audretsch and Feldman (1996), Jafe (1986), Jaffe (1989), Cohen and Levinthal (1989), Acs et.al. (1994)

Promising Research Directions in the Measurement of Technology Transfer

Some early measurements of technology transfer relied on available data, which was not always adequate. But in the past two decades, evaluators have made substantial progress. They no longer look "under the lamppost" (where the light was good but the target item may not have been hiding) and instead use metrics, a value of which can be used to determine if goals have been met. For example, it is straightforward to count patents as a measure of success, but the existence of a patent does not indicate whether or how frequently the patented technology is being used. However, when one patent is cited in another patent application, the citation implies that patents are building on each other; the technology is being amplified or extended. Today's patent databases now include detailed and complex adjustments for citations, more accurately reflecting the activity related to a single patent's utility and adoption. Similarly, measuring Web hits to science databases captures a sense of the activity related to a particular idea. Each link requires permission for accessing the confidentiality-protected source records, in addition to confidentiality protection protocols to satisfy institutional review boards. The complex coding and aggregation of the millions of observations yield a way to compare the utility of one idea with another, as well as the degree to which an idea has penetrated its target community.

To support the analysis of how innovations are being embraced, George Washington University is creating "innovation networks" databases. These repositories require laborious exact matching of diverse files from different federal agencies and updating of those files over time. But the information they contain reflects relationships not visible in any other way. For example, a category called "transfer mechanisms" documents many of the process characteristics not normally collected in records of laboratories, universities, and firms. The database analysts have made serious attempts to measure intra-organizational process characteristics that are relevant and important, far beyond the numbers that are readily available or that are easy to obtain.

Whereas early attempts at transfer-related measurements were relatively simple, current measurement efforts are more difficult but richer. For example, the econometric analyses underlying "knowledge spillover" research can be statistically complex and computationally demanding, but they provide important insight into the degree to which knowledge in one field is applied to other fields. Here, the form of technology transfer is not necessarily toward immediate commercialization, but is simply the beneficial sharing of know-how and knowledge.

Still, there is room for improvement in data collection and analysis. No particular metric is appropriate for all applications, nor is any particular analytical tool correct for answering every question. Some promising avenues for research have only recently opened. Yet the principal findings (sampled in Table C.2), even from a field barely 20 years old, are already varied and useful. They point in some instances to patterns worthy of closer attention from practitioners of technology transfer and from policymakers. Other findings hint at patterns that should now be examined in directed research.

Among the measurement issues yet to be investigated systematically are the generalizations posited by participants in the PCAST Technology Transfer Forum on December 12, 2002, which were generated from their own experiences and are listed in Sidebar C.2. These statements should be considered hypotheses whose generality is yet to be established.

Sidebar C.2—Issues Related to Technology Transfer Measurement (from Forum Participants)

Perceptions of Technology Transfer Forum participants:

- The inventor must be involved in technology transfer, especially early in development—for his or her expertise and vision—for the transfer to succeed.
- A greater number of revolutionary technologies spin out into new small companies, and not large established firms.
- Vis-à-vis private industry, the national laboratories are better at building small numbers or three of something, rather than mass producing a great many.
- Once a company has worked successfully one time with a laboratory or university, the process is much easier thereafter.

The statements from the forum participants in Sidebar C.2, combined with other measurement issues and contexts, suggest ten research challenges that merit investigation:

1. Relating and integrating analyses of direct and indirect metrics. Direct and indirect measurements are sometimes two distinct bodies of work conducted by people in different disciplines with different orientations and tools.
2. Integrating analyses of direct and indirect metrics? by building data sets that combine organization-level transfer mechanisms with the firm characteristics used in spillover analysis.
3. Identifying fields other than genomics in which Web hits to science databases can characterize the transfer.
4. Attending to the different cultures in which developers and inventors, university and laboratory transfer offices, and industrial firms operate.
5. Incorporating risk, particularly by identifying where in the process risk is assumed, and taking risk into account in both measurement and analysis.

6. Understanding the impact on technology transfer of the shift from government to industry as the major source of R&D investment.
7. Extending the research now under way that describes and explains the internationalization of innovation and transfer.
8. Examining the effects of technology transfer attaining the major goals of government, universities, laboratories, and industry. Such goals might include productivity growth, faculty retention, local amenities to facilitate hiring, and increased stock values, respectively.
9. Moving beyond description and analysis toward direct evaluation of the effects and effectiveness of relevant laws and regulations.
10. Carefully specifying the disciplinary and organizational domains in which particular research findings are applicable.

Summary

There are several mechanisms for transferring technology. The main ones are fairly well-understood. They include licensing, cooperative research and development agreements, technical assistance, reimbursable work for nonfederal partners, sharing of facilities, exchange programs, collegial interchange, publications, and conferences.

There are also many ways to measure and quantify technology transfer. The applicability of each measure depends on many things, including the goals of the organizations involved, the degree to which the measure is objective or subjective, and the accuracy and appropriateness of the way the data are collected and analyzed.

Ultimately, assessments of technology transfer depend on how success is defined. Although setting goals may seem straightforward, the nature of collaborative efforts and diverse notions of success across different organizations and cultures can make it difficult to determine if the goals have been met. Thus, addressing many measurement challenges depends on developing clearer views of success, both in the short-term and long-term.

Appendix D. Toward Finding Best Practices

The situations in which technology is developed and adopted are numerous and diverse, and each situation has its own particular characteristics. Identifying best practices requires a shared sense of what is meant by "successful technology transfer." As indicated in Appendix C, notions of success differ, depending on the context and intent of the transfer, and measures of success depend on one's goals. Assuming it is possible to measure overall success within some context, we can then identify those practices that help to meet those goals. That is, measures of success, even when they differ from one situation to another, can shed light on which technology transfer activities encourage movement from concept to reality to goods or services.

This appendix builds on this understanding of success by describing how to seek a set of practices that facilitate technology transfer, derived from the accumulated experience of universities, national laboratories, and corporations. The appendix also highlights several practices that seem likely to promote effective technology transfer and, thus, are good candidates for closer examination.

In this appendix, we address two main questions:

- What are the important variables of a framework for defining best practice?
- How can these variables help in modeling and evaluating candidate best practices?

The Search for Best Practices

Most sources of best practice derive from stories that are published or publicly presented. Lessons emerge from the experiences of others that are shared in forums that include professional societies (e.g., the Association of University Technology Managers), journals (e.g., the *Journal of Technology Transfer*), and Internet bulletin boards (e.g., Techno-L Digest).[32] These sources may reflect a variety of evidence, ranging from carefully measured variables (such as the number of people involved, the amount of money spent, and the time to market a technology) to subjective and varied opinions about which practices and products had the greatest positive impact on a transfer's success. In seeking credible evidence of best practices, it

[32] Techno_L Digest is a discussion forum for patent attorneys, technology transfer, and licensing professionals in universities, government, non-profit research institutions, and in private industry. It is hosted at http://www.uventures.com/ (click Techo-L).

is important to frame a search in the context of a search for variables and their relationships. That is, it is vital to model a particular technology transfer process, define measures of success for activities and outputs, identify the variables involved, and look for relationships that will indicate whether certain inputs and relationships yield certain outputs or outcomes.

Thus, the first step in gathering evidence is finding descriptions of past practices and outcomes. In examining each description, it can be useful to pose several questions about what was done in the past:

- *What are the risks in technology transfer?* Each element of technology transfer has its own set of risks. Moreover, the more revolutionary, rather than evolutionary, the technology is, the greater are the attendant risks. However, the potential payoffs are high, so it is incumbent upon all parties to recognize the risks in each other's areas of responsibility and to work collaboratively to reduce them.
- *How much support was provided internally and externally?* Support may include management, technology/research staff, and technology transfer administrators. Trust and a common understanding of expectations may also play a role in support and guidance.
- *What are the key activities in the model of technology transfer that was used?* What steps were taken, and what are the dependencies among the steps? That is, which things had to be accomplished before other activities could begin?
- *What are the roles of the key actors in the technology transfer model?* It is important to find out who performs each activity and to understand the organizational hierarchy—i.e., who reports to whom?

In looking carefully at examples of technology transfer, one can identify variables associated with the issues of successful technology transfer and the way they were resolved. Among those variables might be

- Institutional incentives
- Organizational culture
- Job descriptions
- Performance evaluation measures
- Disclosure and patenting procedures
- Previous experience with technology
- Previous experience with technology transfer
- Expectations of outcome
- Relevant standards
- Time horizons
- Channels of communication

- Cost
- Conflicts of mission (in terms of discipline, ownership of results, and such).

We use these variables and their relationships to build candidate models of how technology transfer was accomplished, either successfully or unsuccessfully.

Finding Candidates for Best Practices

This section discusses a preliminary set of practices and barriers that motivate investigation of new practices for improving technology transfer. The selection is based on a review of the literature, responses submitted to the questionnaire associated with the PCAST forum, and a limited number of additional interviews of university, national laboratory, and corporate actors involved in technology transfer. Despite differences in organizational missions, structures, and constraints, the following practices were mentioned by many forum participants and seem to apply equally across many organizations.

Organizational Aids for Technology Transfer

Successful implementation of technology transfer policy requires support at all levels of an organization. Three especially important organizational activities include:

1. Establishing a technology transfer office
2. Identifying and valuing intellectual property, including an appropriate intellectual property strategy (which may be sector-specific)
3. Creating mechanisms and incentives for getting researchers involved in technology transfer.

We next consider each of these in turn.

Technology Transfer Office. Skill at technology transfer generally improves as organizations become more experienced at it. The learning curve is seldom smooth, however, and there are numerous tales of frustration. A well-trained technology transfer office staff whose mission is supported by the organization may make learning easier for the rest of the organization. The technology transfer office staff can possess technical, business, and legal skills to work effectively with technical staff to identify, evaluate and develop a strategy both for identifying intellectual property and for patenting, marketing, and licensing it.

One of the most important roles of a technology transfer office relates to all participants in the technology transfer: working toward an understanding of each stakeholder's needs, priorities, risks, and statutory limitations.[33] The differences in culture, time scales, expectations, rewards, and priorities, among other differences, suggest that the investment in learning to work together is best recouped through ongoing long-term relationships between transferor and transferee.

Identification, assessment, and valuation of intellectual property and decisions on appropriate intellectual property strategy. Once technology reaches a certain level of maturity, it is ready to be considered for transferring to industry. If the number of invention disclosures is a useful measure of success, then technology transfer organizations can increase the number of invention disclosures by training the researchers to recognize potential intellectual property. Providing streamlined procedures for disclosure and patenting can develop a positive feedback loop, encouraging continued engagement of the researchers. Intermediary groups or networks may also be set up to identify inventions and assist in their evaluation. A review board comprising experts from different fields may also be valuable in identifying cross-cutting applications, challenging researchers to broaden the scope of their work.

Decisions about valuing intellectual property depends on several factors, including the promise of payoffs derived from patents. However, the payoffs are generally smaller than expected. For example, as Agrawal and Henderson report, "Most [MIT Mechanical and Electrical Engineering] faculty members estimate that patents account for less than 10 percent of the knowledge that transfers from their labs.[34] Moreover, most laboratory inventions are far from ready for commercial implementation, even though they may have great potential. That is, additional steps are usually required to take an invention through development and into commercial practice or production. At the same time, it is difficult to interest firms in immature technologies without a prototype or proof of concept. Thus, value from the perspective of the university is not the same as value from the perspective of a commercial investor.

Any model of the intellectual property process (creation, identification and capture) must include these notions of valuation. To see how they may differ, consider the example of computer science intellectual property (IP). At the Computing Research Association's Snowbird conference in July 2002, J. Strother Moore of the University of Texas at Austin refuted the popular argument that computer science IP generates substantial revenue for universities. Moore

---

[33] The following quote is an example of the oft-cited corporate view of collaboration with universities: "Typically at present, negotiating a contract to perform collaborative research with an American university takes one to two years of exchanging emails by attorneys, punctuated by long telephone conference calls involving the scientists who wish to work together. All too often, the company spends more on attorneys' fees than the value of the contract being negotiated. This situation has driven many large companies away from working with American universities altogether, and they are looking for alternate research partners. Universities will in general receive far more funding in the form of research contracts from high-tech companies than they will by licensing technology, because of the short life of such technologies and the fact that it is always possible to substitute one technology for another" (Williams, 2002).

analyzed the licensing income of universities and concluded that while IP is indeed a powerful revenue generator for universities, only a fraction of the fees comes from licensing computer science or electrical and computer engineering innovations.[35] A similar analysis by Dave Hodges, former Dean at the University of California at Berkeley, led to significant changes in the flexibility of University of California campuses in negotiating sponsors' rights to university intellectual property developed in computer science and electrical engineering-based sponsored research.[36, 37]

In the fields of biotechnology and medicinal research, individual patents have potentially greater commercial value because of their closer association with a specific application.[38] The rapid developments in these fields have far outpaced the regulatory system's ability to address questions raised by the new technologies, such as whether clinical or other trials are necessary, or whether DNA-related research may be patented. The subsequent bureaucratic delays and lengthy processes have contributed to turmoil within the research communities, as expressed by several participants at the December 12 forum.

In other, more mature industries dealing with materials and manufacturing processes, such as chemicals or semiconductors, individual patents are less important than "baskets" of technology because companies are often heavily cross-licensed. Companies are interested in access to ideas at the scientific frontier and access to high-quality graduates, who are effective vehicles for the transfer of academic research results to industry. For firms with these objectives, extensive requirements for specification and negotiation of the disposition of intellectual property rights from collaborative research may impede such collaboration.

Organizational mechanisms and incentives for researcher/inventor involvement in and support for technology transfer. Successful technology transfer often requires the support and specialized knowledge of the researcher/inventor beyond the formal licensing of a patent. In defining the organizational goals and objectives for technology transfer, forum participants made it clear that mechanisms for enabling and encouraging the extra commitment of time and effort by the researcher need to be considered within the context of the other organizational priorities. For example, a manager of a federal research facility noted the difficulty of getting laboratory

---

[34] Agrawal and Henderson (2002), pp. 44–60.

[35] Moore (2002).

[36] August 30, 2000, memo from the University of California at Berkeley Office of Technology Transfer on the Electrical Engineering and Computer Science Intellectual Property Pilot Program. (http://patron.ucop.edu/ottmemos/docs/ott00-02.html).

[37] Much computer-related intellectual property is copyrighted, as opposed to patented. This may account for some of the difference in licensing rates compared with other disciplines.

[38] Mowery (1998).

engineers to spend time with start-up firms when they were already overworked and not rewarded for some technology transfer activities.

Various mechanisms can be used to express technology transfer priorities. For instance, universities may allow faculty time for consulting. On the other hand, statutory restrictions on consulting at national laboratories may present a barrier to effective technology transfer. "Entrepreneurial leave" was noted as an incentive offered by some institutions. Other forms of incentives include percentage of royalties or licensing fees and the inclusion of technology transfer as one component of the job description and in the personnel evaluation criteria.[39]

"The Valley of Death" (Between Research and Manufacturing)

Development can be the riskiest and most essential element in technology transfer. It is the juncture where research ideas, perhaps matured to the proof-of-concept or prototype stage, meet practical considerations (measured according to concepts such as defect levels and yields), economic realities, and the vagaries of the marketplace. Several forum participants called this divide "the valley of death." Many laboratory inventions are far from the commercial stage, even though they may appear to have great potential. Indeed, one forum participant noted that researchers build prototypes in threes and fours, but that production level is a far cry from the hundreds or thousands of copies of a product needed for a viable marketing effort. The chasm between the immature state of the work emerging from the research laboratory and the level of maturity needed to attract a large corporate transferee was identified by many forum participants and survey respondents as the largest barrier to technology transfer.

Technologies can be considered either *evolutionary*, in that they build on what is already known and used, or *revolutionary*, in that they represent great leaps forward. Generally, startup companies are the only means of introducing revolutionary technologies, yet venture capital for small to mid-size startups is becoming more difficult to attract.[40] Here the valley of death is particularly wide. Numerous approaches to bridge it are being tried, including alternative funding for internal or external maturation or incubation of a research project and cooperative development agreements. Business acumen is critical at this stage, along with the continuing

[39] The modification of job descriptions and performance criteria in the research organizations (universities and national laboratories) needs to be carefully considered in the context of the organization's primary mission. Technology transfer would be only one of many criteria, and the job descriptions should be sufficiently flexible to accommodate the variety of roles that a researcher/technologist may take on.

[40]Statements from survey respondents, PCAST Forum on Technology Transfer, Dec. 12, 2002, RAND, Arlington, Va.

support of the transferring researcher to ensure that the technical know-how is effectively transferred.

Categories of Best Practice

Sidebar D.1 illustrates some of the activities that can be used to enhance identification and transfer of intellectual property, based on actions cited in the research literature. A broader literature survey, supplemented by comments from forum participants, suggests ten categories of best practices that can be considered for evaluation:

1. Ideas and mentors
2. Intellectual property awareness and capture
3. Institutional incentives and culture
4. Students
5. Intellectual property administration
6. Methods for assessing the value of research, including the management of the intellectual property portfolio
7. Project incubation and maturation
8. Licensing intellectual property: culture, management and alignment
9. Marketing inventions, innovations and technologies
10. Education.

Appendix C presents a table of forum and survey participants' comments related to these categories and annotated with categorical references. This table can be gleaned for additional candidate best practices.

Sidebar D.1: Candidate Activities for Improving Technology Transfer of Intellectual Property

Perceptions of Technology Transfer Forum participants:

- Researchers can identify potential intellectual property. They should understand that the term "intellectual property" has a broad scope, meaning that it can be interpreted as different things under different statutes.
- Some institutions actively pursuing technology transfer have tried to ensure that they capture all the intellectual properties developed in their laboratories by maximizing invention disclosures (and thus their inventory of licensable technologies) and by patenting as many promising disclosures as budgets permit.

- Technology transfer networks or scouts, groups of trained researchers from within a university, or technologists from industry may be given wide access to government laboratory or university research facilities to identify technologies that may be of commercial interest.
- Students often serve as an effective means of technology transfer as they gain knowledge through their research and are subsequently employed in the private sector. However, conflicts of interest may arise among student, professor, and university goals. Explicit policies sometimes address these concerns.

Evaluating the Evidence

A great deal of anecdotal evidence supports any given practice. But an essential step in any assessment of a candidate "best practice" is to look at the body of supporting evidence in its totality. The relevant model of technology transfer, the appropriate measures associated with it, the data collected and reported in controlled situations, and the anecdotes are all components of an argument in favor of the practice. These components can then be assessed to determine whether they support the notion that a particular practice is effective. Critical questions include:

- How well was the practice implemented? That is, what steps were followed, and were they followed thoroughly and in the proper order?
- What were the conditions before the practice was implemented? Could these conditions affect the practice's results?
- Are there other activities or situations that could account for the results? That is, is the practice the only reason that things turned out as they did?
- Is the practice repeatable? Could the same thing have happened if different people performed the practice, or if the practice were implemented a second time?

Further research is needed to examine the state of the art and the state of the practice of technology transfer. A great deal has been learned, especially in the past 20 years. But a great deal needs to be done before an activity can be declared a best practice.

Summary

Defining best practices depends on how technology transfer success is defined in particular contexts. Current understanding of best practices is underdeveloped. Interesting observations and anecdotes give some clues to what works well and can serve to stimulate discussion and provide a basis for deliberations. However, a framework for comparison and more rigorous research are needed to develop a sound approach to evaluating evidence on successful practices.

Appendix E. On-Line Questionnaire on Technology Transfer and Compilation of Responses

Technology Transfer of Federally Funded Research Questionnaire

Background

The Science and Technology Policy Institute at RAND (S&TPI) is collecting information from individuals and organizations involved in technology transfer about experiences with technology transfer, the identification of "best practices," and the "barriers" to implementing best practices. The results of this questionnaire will be summarized in an S&TPI document on technology transfer for the use of the President's Council of Advisors on Science and Technology (PCAST) and others interested in the topic. Although we will be able to identify your contributions through the registration process, your comments will not be attributed without your approval. Moreover, we will use your contact information to send you a copy of the results.

By technology transfer we mean any of the following activities:

1. Informal discussions of research results and techniques between individuals supported by federal funds (transferors) and individuals working in the private sector (transferees)

2. Formal dissemination of research results, for example, at conferences

3. Licensing of university and national laboratory patents to the private sector

4. Cooperative or collaborative research and development between a university or federal laboratory and the private sector

    a. Informal: work initiated out of mutual interest without generation of written agreements

    b. Formal: joint grants or agreements to perform collaborative work

5. Startup of small company based on federally funded research

6. Technical assistance from transferors to the private sector

7. Personnel exchange or loan (professor or student on visit or temporary assignment to company or company technologist on visit or temporary assignment to university)

8. Private-sector use of federally funded facilities

9. Formal exchange (written agreement, e.g., consultant) of nonpatented intellectual property--techniques, skills, the “art” of the practice, computer code, etc.)

Instructions

This questionnaire should take about 5 to 10 minutes to complete. The format includes both checkboxes and written responses. For the questions that require a written response, please highlight the aspects that were most effective or useful to you (please include the context and depth that you would find useful if provided by others).

You may answer this questionnaire on the bases of your personal involvement and experience in your organization’s technology transfer or on the basis of the wider experience of your whole organization.

If you have additional information that you would like us to consider, please forward it electronically to ttsubmit@rand.org or send it to Tech Transfer Forum, S&TPI/RAND, 1200 South Hayes Street, Arlington, VA 22102.

A copy of the report will be posted on the S&TPI Web site.

Thank you for providing this information.

The Questionnaire

I. Demographics and role in technology transfer

A. What is your institutional affiliation? Please check all that apply:

U.S. university or college

Federal laboratory (non-federally funded research and development center [FFRDC])

FFRDC

Large corporation

Small corporation

U.S. nonprofit (noneducational)

State or local government

Federal government (non-FFRDC)

Foreign government

Other (please specify):

B. What is your role in the technology transfer process? Please check all that apply:

University federally funded researcher, inventor, or research manager (transferor)

University technology transfer administrator for researcher or inventor

National laboratory researcher, inventor, or research manager (transferor)

National laboratory technology transfer administrator for researcher or inventor

Company technologist or technology manager (transferee)

Company technology transfer administrator

Company executive

Other (please specify):

C. With which types of technology transfer have you or your organization been involved? Please check all that apply:

Informal discussions of research results and/or techniques between transferors and transferees

Formal dissemination of research results (e.g., conferences)

Licensing of university or national laboratory patents to the private sector

Cooperative and/or collaborative R&D between a university or federal laboratory and the private sector:

Informal: work initiated out of mutual interest without generation of written agreements

Formal: joint grants or agreements to perform collaborative work

Startup of small company based on federally funded research

Technical assistance from transferors to the private sector

Personnel exchange or loan (professor or student on visit or temporary assignment to company or company technologist on visit or temporary assignment to university)

Private-sector use of federally funded facilities

Formal exchange (written agreement, e.g., consultant) of nonpatented intellectual property--techniques, skills, the "art" of the practice, computer code, etc.

Other (describe):

II. Experiences with technology transfer

A. Please describe your organization's primary methods or processes for facilitating technology transfer (please identify the type of technology transfer involved using the list provided above).

B. Describe the most serious barriers you've encountered (please identify the type of technology transfer involved).

III. Incentives for supporting technology transfer

A. Does your organization offer monetary rewards for submission of patent claims or granting of patents? Yes / No

How effective do you believe them to be?

B. Does your organization provide recognition and/or rewards for time and effort spent on technology transfer? Yes / No

How effective do you believe them to be?

C. What factors do you, as a transferor or transferee of technology, feel are important to your individual willingness to contribute time and effort to technology transfer?

IV. Measuring the effectiveness of technology transfer

A. Are you aware of any metrics to assess the success or effectiveness of technology transfer? Yes / No

If yes, please describe them:

B. What do you see as the major problems associated with measuring the success or effectiveness of technology transfer?

V. What other approaches can we learn from?

A. What methods or processes (described above) do you consider particularly effective for the transfer of technology (please identify the type of technology transfer involved) and why?

B. Where else should we look for relevant best practices in the transfer of technology?

May we follow up with you if we have any questions? Yes / No

The on-line technology transfer questionnaire described above allowed many individuals from all organizations and roles to comment on many aspects of technology transfer. This portion of this appendix summarizes comments on two of the more important issues—perspectives on serious barriers to technology transfer and effective methods for technology transfer.

The comments are grouped by affiliation, i.e., college/university, federal laboratory/FFRDC, large or small corporations, nonprofit organizations, and the U.S. government. The categories of survey responses listed here are based on the responses to Table E.1.

Key to Categories of Survey Responses	
a	Ideas and mentors
b	Intellectual property awareness and capturing intellectual property
c	Institutional incentives and culture
d	Students
e	Intellectual property administration
f	Assessing the value of research and intellectual property portfolio management
g	Project incubation/maturation
h	Licensing intellectual property--culture, management, and alignment
i	Marketing inventions, innovations, and technologies
j	Education

Table E.1

Survey Responses by Category

	Effective Methods (Responses to question V(A) of survey)		Serious Barriers (responses to question II(B) of survey)	
Affiliation	**Comments**	**Category**	**Comments**	**Category**
College/University	User-friendly, efficient technology transfer office with highly competent staff that can effectively serve, assist, and educate the faculty and students to facilitate the transfer of their ideas from bench to market	e	Early-stage university inventions/discoveries that have any potential for commercialization require development investments to reach marketable status. These pre-seed funds are generally not available from public or private sources.	g
□	A core group or critical mass of highly creative and entrepreneurial faculty who are astute and willing to work within the university guidelines.	c, j	Deficiencies in the Office of Technology Transfer, which simply lacks enough staff to find the appropriate industry contact that might enable the transfer of technologies.	e, h
□	Exceptional negotiation skills within the technology transfer office to structure and conclude all business deals.	e	The lack of resources to invest in the "development" of new discoveries. Most university discoveries are very early stage, and because of the academic imperative to publish are submitted as provisional patent applications at the very earliest point of discovery so that the faculty member can publish a paper disclosing the invention. What we have found, however, is that it is then quite difficult to find funding to build a prototype and provide a real proof of concept. Universities do not have these kinds of investment funds, and it seems that many promising ideas probably die	g

		because of this lack of resources.	
A university President who is supportive of this effort and has a clear understanding of what works and what does not work within his university.	c	Naiveté and lack of knowledge of university researchers in this field, yet many believe they "know it all" and are not willing to devote the time to become educated, while aspiring for patents and spin-off companies.	b
Intellectual property mapping to assess opportunities.	f	Negotiating agreements with large corporations interested in sponsoring research with modest funds and expecting to own any and all intellectual property in the field of research.	h
For Biotech: Get a patentability opinion to see what might dominate the invention and whether it has a good chance of being developed. We do NOT do freedom-to-operate assessments because we think that is the duty of the licensee. The latter could create some liability for the university also if we were to use it as an incentive for the company to license a technology.	f, h	Conflict issues are serious when an inventor or entrepreneur, who is a university faculty member, does not recognize or accept the boundaries between his spin-off company interests and his university obligations.	c
We use faculty advisory committee made up of people who have some knowledge of the tech transfer process . . . this works for some institutions if the volume of disclosures to be processed is manageable.	b, f	Identifying market opportunities requires experienced personnel	e, i

(1) Success is enhanced if the inventor is an effective champion and advocate for the technology, i.e., articulate, aggressive, receptive to contact from companies, but not possessive. (2) For early stage technologies, a combination of licensing and sponsored research is often critical to the successful commercialization.	c, h, i	University politics	c
Institutional seed grants for new ideas and incubators for development of new ideas are very helpful.	a, c	It's difficult to get firms to respond unless we have a lead in contacting a specific research scientist who knows our faculty researcher. Even then, to get a response for the business developer is sometimes not easy.	i
Having good university relationship with companies that may have an interest in new and developing technologies.	e, h	We want a way to find out the needs that companies have (they sometimes guard that information closely), then see if our tech portfolio relates to that need. Making the match between the ones who have technology versus those who need it is a challenge.	i
		Biotech is often very early stage, with lots of development to be done before it reaches commercial reality, hence it's very difficult to place a value on it and to do pre-market research.	f, g, i
		Reach-through provisions in material transfer agreements; assignment requirements of intellectual property in sponsored research agreements	e, h
		Lack of adequate staffing resources to provide the evaluation, assessment, education and service necessary to bridge the cultures of industry and universities and make the case-specific arrangements that are necessary to achieve the desired results while satisfying the mission and objectives of	j

			both sides.	
□	□	□	The mixed signals coming from every level of government about university-industry relations. Is it good or bad? Is it a conflict or is it necessary to transfer results? Etc. The uncertainty of individual administrators and faculty leads to confusion, slow deal making, and paralysis in some cases.	f, h, c
□	□	□	Slowness of negotiation MTA or other agreements between University and company.	e, h
□	□	□	Office is generally slow and does not have a good understanding of the science. Patenting issues are out-sourced and several of the firms used have not been particularly good.	e, h
Federal Laboratories/FFRDC	Licensing agreements…we are given the greatest flexibility in negotiating terms and conditions of these agreements.	h	Can't take equity in startups; researchers' ability to consult is statutorily limited; researchers can't take "entrepreneurial leave" to help a company get started in the commercialization of a technology invented in the lab.	c
□	The MBA Intern program has been effective in helping us to evaluate technology for commercial potential. It has also identified business talent directly relevant to technology transfer programs such as entrepreneurial development and training, business planning, market assessments, and business formation. The technology commercialization executives working	e, f, i	Requirement to advertise availability of inventions for licensing for 90 days hampers ability to move quickly.	e

closely with the intellectual property coordinators in the technical divisions of the Laboratory have been effective in stimulating and identifying new intellectual property, which feeds all our other technology transfer processes.			
Our Strategic Partnership Program has been effective in identifying long-term, mutually beneficial partnerships that stimulate repeat business for technology transfer. Our Industrial Fellows Program sends Laboratory staff to strategic partner companies to further develop these types of relationships.	a	insufficient resources directed at marketing of technologies to potential partners	i
Our internal training programs in intellectual property management, entrepreneurships, and commercialization have identified many new internal clients and technologies for us to transfer. The new Technology Maturation Fund will be very important in moving technology development closer toward commercial applications. Our cooperation with the Los Alamos Research Park supports both our collaborative R&D goals with partners as well as our new business start-up objectives for the region. Finally we have an external advisory board composed of experts from academia, industry, other federal labs, and regional business development organizations, that helps us develop and implement our programs at the Laboratory.	j, b	Lack of funding to bring conceptual technologies to working prototype stage	g

□	We have had the most success with our Work For Others program because the partner provides all of the funding to support the effort and licensing. There has not been any funding to support technology transfer efforts from the DOE in many years.	g	Uncooperative or unavailable inventors	c
□	□	□	No management support for tech transfer efforts	c
□	□	□	Cumbersome DOE requirements for licensing agreements	e
□	□	□	Lack of department funding to pay for technologies and to pay for technologist's time for participation in tech transfer program	c
□	□	□	The real or apparent economic downturn is discouraging companies from investing in TT (technology transfer) from national laboratories.	other (econom y)
□	□	□	DOE boilerplate TT agreements do not allow sufficient room for negotiation.	e
□	□	□	The biggest barrier to technology commercialization is the lack of funding to develop a raw invention for commercial applications. Few DOE programs have the mission requirement to transfer technology beyond direct mission applications to other commercial applications. This leads to many DOE-funded inventions being stranded in an undeveloped and immature state that does not attract commercial interest. Industry asks for further development and demonstration to reduce the risk in unproven technologies.	g

□	□	□	Another major barrier we always face is time to negotiate and execute technology transfer agreements with industry. Many of these agreements must be approved by the DOE. Delegation of approval to the laboratory would speed time to complete agreements. The "U.S. Competitiveness Clause" in DOE CRADAs needs to be reviewed in light of the large number of multinational businesses doing business in the U.S.	e, h
Large Corporations	□	□	The technology is often too immature. Its application and business value has not been determined precisely enough.	g, f
□	□	□	Disparity between legal representatives on priorities	e, h
Small Corporations	Moving technology from the university to the public space. Knowledgeable people at the university and public sector. One needs to understand the end use of the technology (not to pursue something just because it's new technology). There must be an end game, a product which will either improve or assist the end users.	f, h, i	Usual barriers involve the university TT office. There is no consistent process from one university to the another. Additionally, there are universities on the West Coast who don't have qualified personnel running their transfer office thus causing delays and unnecessary paperwork.	e, h
□	□	□	Lack of organizational leadership and support for doing tech transfer. Problems with organizational culture supporting tech transfer among research faculty or staff.	c
□	□	□	Lack of understanding of the true value of new inventions.	b
□	□	□	Lack of resources to support very early-stage, high-risk, proof-of-concept research on new inventions	g

□	□	□	Conflicting attitudes and expectation of the value of tech transfer on the part of various stakeholders: Researchers, Leaders of research organizations, Economic development interests, Federal research managers, Businesses.	i, f
□	□	□	Informal and formal dissemination of technology--communication of technology (via papers, presentations) not written or formatted by the transferor in a way which is easily understood and applied by the transferee (e.g. an academic paper which describes an interesting technical development but not its implications for practice).	b
US Nonprofit	Organizational Effectiveness: partnering practices to build the will of the partners to mutually drive success…and to weed out the likely unsuccessful partnerships before wasting energy on them.	j, h	Time required to initiate longer-term agreements. Funding directives from Congress truncating longer-term work early.	e, h
□	□	□	Unrealistic valuations of existing and expected IP (intellectual property).	f
□	□	□	Cultural differences toward urgency around milestones. Partnerships mandated to carry social baggage requiring burdensome reports and other paperwork.	c
□	□	□	Lack of control over use of IP by others which may lead to deep-pocket liability by partners uninvolved with the disputed application.	h
□	□	□	Identifying methodology to move from informal to formal relationship with the federal government in a noncompetitive bid format.	e, h

U.S. Government	It seems to me that the people who are developing technology come to Washington to get support for R&D and help in marketing new products. There is no agency or group available to serve as a clearinghouse for new technology. Developers of technology don't know how to get funding pr how to market their products and the government agencies that need the technology don't always know where to go to get the products they need. It appears to me that there is a need for someone to match up the providers of technology with the users, the companies looking for new products, and venture capitalists who might be interested in funding new developments and products.	h, i	Federal conflict of interest statues make it difficult for government employee inventors to become involved in commercialization of their inventions.	c
□	(1) Information Support System supports researchers, patent advisors and tech transfer marketing specialist; (2) Transferring Technology for Industry process described above is labor-intensive, but it is a way of identifying as many potential solutions as possible. It gives the industry the opportunity to review the potential solutions and select the most appropriate technology based on the requirements.	i	Internal politics of the organizations affected every project.	c
□	□	□	Economics--the industry's bottom line. The technology could improve the farmers' income or be more environmentally friendly, but if it didn't improve the bottom line for the manufacturer, the technology didn't get transferred and commercialized.	f, *New (Monetary value versus social benefit)

Other	As part of its effort to identify barriers to tech transfer, the FLC prepared and submitted an issue paper to the White House OSTP regarding the need to reform the federal innovation system and provide the necessary authority for mission-oriented federal labs to be able to work with the network of university-based Rehabilitation Engineering Research Centers, which develop assistive technologies for the elderly and persons with disabilities. We also utilize the services of the FLC National Advisory Council (NAC), a committee composed of diverse groups of professional individuals from industry, academia, government, and national associations...that facilitate the utilization of technologies developed at federal labs by suggesting methods and practices that accelerate the transfer of knowledge. They are also involved in developing and implementing our Strategic Plan, as well as recommending changes and improvements.	e, h, i	Raising money to fund startup companies based on university or lab technology.	f, g
☐	The use of Memorandums of Agreements (MOAs) are many times more effective technology transfer instruments that CRADAs. Mutual exchange of data/information/technology can be more easily accomplished through the use of MOAs.	h	Cost of U.S. Patent filing and inadequate budgets.	f
☐	Alliances and CRADAs work when they are properly negotiated and administered. They could be made more effective if they were used to spin out companies, involving lab employees from the Lab.	f, h	Support and participation by academics in invention disclosure.	b, c

□	Public databases are probably the best example. Genbank and its associated search tools have a value to the scientific community that is immeasurable and would be impossible to do without. Perhaps creation of public storage and dissemination facilities for reagents, tools, techniques, patients, etc., would be established. In this case, an investigator with a unique material could simply supply this to a central repository and public access would be assured with no additional burden on the investigator.	a, c	The most serious barriers to government technology transfer is the withholding of the best terms available to a licensee, notably the commercial exceptions clause that assures that a licensee's investment will not be jeopardized by having to grant access to its background patents to a potential competitor. Many negotiations have been turned sour when this provision is introduced late after much anxiety on the part of the licensee. Since it is an inevitable concession, it should be formalized and offered as part of the licensing package in the standard language up front. I believe this will minimize the time in negotiations, too.	h
□	□	□	The PRIMARY barrier to effectiveness has been internal political resistance due to turf battles and perceived threats to established spheres of influence.	e, f, h
□	□	□	As a requestor, the most common barrier I have experienced is ignoring of requests by other scientists, followed by requirements for completion of MTAs that cannot be approved by our institution due to restrictions. Moreover, many of these MTAs cause problems with other reagents already in the lab from other investigators having their own MTAs so that "third party" agreements have to be negotiated that take months or years to complete. As a supplier, the survey process before an MTA is issued is often more trouble than its worth so I often just send the requested materials and ask the recipient not to send it to anyone else without permission. This usually works just fine.	a (transfer of material between labs to foster academic research)

Appendix F. Excerpted Comments from the December 12, 2002, Forum

During the December 12, 2002, PCAST Technology Transfer Forum, the afternoon portion of the agenda was reserved for open public comments and an open discussion. This allowed attendees the opportunity to raise issues on any aspect of technology transfer. A recording of the sessions allowed a transcript to be made. This appendix presents excerpted comments from the afternoon open sessions. They are grouped by general category (i.e., Serious Barriers; Effective Methods; Primary Methods; Metrics; and Other), and are then further grouped by general affiliation (i.e., Universities, Large Corporations, U.S. Government, etc.). Because some entries apply to more than one category, they may appear more than once.

Serious Barriers to Technology Transfer: Concerns, Suggestions, and Recommendations

Colleges/Universities

▪ What we are finding nowadays is that when we are starting with radically new technology, not improvements to known ways of doing things, that the most common method nowadays is a start-up founded by the inventor, sure, and often a graduate student, being the very best form of technology transfer. But then what happens? And this is happening in biotechnology, nano technology, you name it. Then the little company steps up the technology, starts to identify the killer applications, and forms the strategic alliances with the large companies. And this process has been really growing in the last eight or nine years. The large companies having a reluctance to take a great risk that will be very long-term, because of the Stock Market. The risk is being taken by the high-risk venture capital. And then small companies are becoming the bridge to the large company. And I don't think anybody has been studying that much into the new form of the transfer that I think is becoming critical in the really cutting-edge technologies.

▪ But when I talk about technology transfer, licensing out start-ups, you can't license paper for early stage technologies. The inventors must be involved to sell the vision. The problem, and I don't have an easy answer with the federal labs is that people do not have consulting rights.

▪ There was a conflict in the minds of the senior management of the GOCO [federal laboratory] whether they wanted to encourage technology transfer towards the national effort of encouraging technology transfer, or whether they were scared to death, because a successful start-up drained some of their best, brightest, youngest, most innovative people out of the labs. It's a dreadful trade-off for the manager of a high tech laboratory. The universities solved it by -- not solved it, but at least partially solved it, first of all, because they have the consulting privileges, which I don't think is a possible solution. And so it can be a continuing involvement between the inventor and the technology transfer. And second, universities solved it by leaves of absence. So I would encourage this [for federal laboratories].

▪ We need a national dialog on role definition.

▪ It is true that the significance of background inventions, and the blocking effect that they might have on more recent collaborations, have been recognized as a problem that was not on our screen maybe five years ago.

▪ The high cost of licensing university technologies.

▪ So even within the universities, the different objectives have different importance across different groups. Secondly, it's the case that very few technologies, and even fewer universities, make a lot of money. Most technologies earn small, read zero, license income. If you really consider license income as the primary motivation for universities in technology transfer, then if you look at the Association of University Technology Managers (AUTM) data, you can easily make the case that most of these guys ought to shut down their offices. They simply are losing money. That does mean this is not something they ought to be engaged in. If profits were the only thing, they ought to shut down.

▪ It depends on having a technology transfer office that can rapidly respond if it wants to file or not. We, as a matter of policy, will not ask our faculty, particularly our graduate students, who need it for their careers, to delay publication.

▪ That means if they come to us, we have to make the decision very fast. You are not going to be able to do a full market survey to justify it. This is where one change in patent law, the provisional filings, could have an effect. Because if it were somewhat less expensive to say, okay, we're going to do it.

▪ We were talking about incentives to get inventors, scientists at the federal labs involved in the technology transfer process. There is no corresponding system [to universities] within the government and federal laboratory system, which is likely to take the. . .one day a week that faculty at the universities enjoy. And without it, it is a frustrating exercise at the federal labs, because there is no incentive for the scientists to get involved in the same way.

▪ In the university environment, we are under conflict of interest requirements to prove that there is no distortion of the scientific data, because some faculty member may have industry connections, and may use those as an incentive to maybe skew what he or she is providing under federal funding.

▪ I have had the opportunity to work for a world intellectual property organization, and they are making many initiatives to try to streamline everything from harmonization issues, to the electronic filing, to getting rid of the translations. And we sometimes tend to be the slow party in terms of supporting those initiatives. And I think it's important to reduce those costs and those barriers, so we can have broader coverage, and more cost-effective coverage.

Federal Laboratories

▪ I think there is a culture by the inventors or the developers as well, in addition to the timeframe, that makes a difference between those groups in how they participate in the technology transfer process. And the individual who is trying to be a facilitator for a lot of people, the ability of the inventor or the generator to help is really critical.

▪ The federal labs may look at technology transfer as a two-way street. They are looking for benefit of technology coming back to the labs as well. But about the last 12, 14 years the Defense Department particularly has been trying to emphasize the ability to transfer commercial technologies into the defense lab system, because they feel that they don't necessarily have the human technology capability or the fiscal resources to build everything on their dollars.

▪ One of the things that oftentimes causes stumbling is around intellectual property…it can't just be given away for free. If you give it away for free, and give it to everybody, then it becomes of no advantage to anyone. And usually it will just be left on the table. … you need to actually have somebody who is going to, through some licensing or ownership process, have some form of privileged position, or they won't invest the dollars that it takes to take earlier-stage research and put it through the development cycle, and bring it to the marketplace to do that.

▪ Indemnity has been another thing that people have stumbled over in the past. … there is a lot of confusion over exactly what indemnity means, and who gets indemnified for what. And in most cases, the lawyers eventually sort that out on the two sides, but it is something that causes some difficulty.

▪ Time is another problem that we have for a number of different reasons. One is all the different stages that you have to go through, various approvals. It takes time. There is a time factor that is tied up with the anti-competition and fairness of opportunity clauses.

▪ In the private sector they are not used to prepaying for work…. the pre-funding requirement always requires some dancing and footwork to try to make it as palatable as [possible].

▪ Maybe what the nation needs to consider in those orphan industries where there is public good to be served is some form of public-private partnership that will fill that development funding gap, that the venture capital community probably wouldn't step into, because they don't how to reach the very small, segmented markets for some of these kinds of technologies.

▪ In fact, what throttles even consulting at these laboratories is notions of conflict of interest. And the reason is that people can't own equity; even though our laboratory owns equity in companies, individuals do not, nor can they.

▪An individual, an employee of the laboratory, supposedly has the principal allegiance to that laboratory and to the U.S. government through that lab. But they are now under the position of holding equity in a company. And the fear is that now when this person makes a decision about where they are going to file IP, or how they might do something, they will do it in a way that will favor their own personal interest in that private company, drive up the value of the stock, if you will, and do that to the detriment of the United States government. That's ultimately what's the core of the fear.

▪The labs have difficulty sometimes understanding the needs for technology from non-traditional sources. For example, the agriculture labs have worked for decades in biotechnology. That we are just now starting to understand the potential of biosensors for us in agricultural applications.

▪Industry doesn't know how to reach into the federal lab system. We hear this continuously in the context that a lab is not just research and development, it's not the results of research and development, it's also the people. It's the facilities. It's the equipment.

▪There was a comment made about perhaps the labs or the universities are generating capital to go back into the laboratory from the royalties. And I wanted to point out -- and that is maybe one of the reasons why it is harder, or they don't want to work with industry.

But in reality it is very clear in the law what those royalty payments are used for, and how it can be used. So industry does not need to be concerned that it is generating royalties back into a laboratory. It's very clear how those funds can be utilized.

Large Corporations

▪ We are very interested in technology transfer from universities or national labs, but we are a relatively small player in that we belong to the Industrial Research Institute. Many companies are relatively small players. And the reason is technology transfer from national labs or universities to industry is not always easy. And we do initiate lots of discussions, and lots of those are non-starters. And those are related to requirements in agreements. Those are related to IT rights or licensing terms, royalty sharing, exclusivity, indemnity -- that's a big thing -- and speed to reach an agreement, and then a different interpretation by labs. Why do they want to transfer technology to industry? Those are things that we have problems with.

▪ Is the objective generating cash flow to universities or national labs? If that's the objective of federal research and development, I think that's not the right thing to do.

▪ We need to do more to educate the public, especially patients and consumers about the benefits of technology transfer…. through congressional oversight, we must also educate policymakers in both the executive and the legislative branches. Metrics are an important part of this process.

▪ I think it is a mistake to think that all industry loves the inventor [a lot]. Because in our company, we are a big company, but we reward inventors with hundreds of dollars. It's not thousands or millions of dollars, even an invention that makes millions and millions of dollars.

Small Corporations

▪ What happened to us, and which I think will kind of discourage other venture capitalists was really a timing issue. We went in, and from first meeting in introducing the idea and the team and hiring a CEO who was formerly a director at NASA, we had a series of meetings and submeetings, and we worked our way down from the director of the lab, all the way down to the people who really are the founders of the technology.

And unfortunately for us, that process took about six and a half months. And I think we heard today some comments on the venture capital industry, and successful commercialization is really about timing. And so what we found in going through all the machinations and the submissions of paperwork and the series of meetings, was that this company, One company essentially missed the market opportunity to develop and commercialize some otherwise fantastic technology due the bureaucracy involved in the commercialization process -- putting together a CRADA agreement.

▪ We really didn't see that culture at the lowest levels. We got all green lights at the top levels, at the lab director levels. But when it comes down to working with the individual project managers, at the end of the day it was more work for them. They didn't see the incentive in terms of career advancement or monetary gain, as you might see dealing with a commercial partner.

And we were asking them for extra time, working after hours, this sort of thing, to accomplish a commercial goal, which might be legislated, but really had kind of a negative impact on their day to day life.

U.S. Nonprofits

▪ Without an unexclusive license, which in essence provides freedom to use and practice the resulting research, companies would be unwilling to sponsor university research with private dollars.

▪ The position that a lot of companies take is that it's unfair to have to pay once for the research, and then all the sudden have to come back and pay a second time for an invention that wouldn't have been created but for the private dollars that went to that research. You know, I think a research sponsor expects to be able to use the research that they pay for, and this appears to us to be a normal market expectation.

▪ The interest of private industry sponsors who support university research, and letting them utilize commercialized research results should be protected, again, or else there will be no incentive for the private sector to continue sponsoring university research.

▪ Bayh-Dole is sometimes being applied unreasonably in situations in which there is little or no federal sponsorship of university research. And even in cases where the government provides most of the funding, industry sponsors by virtue of paying at least part of the research, have some interest and some rights in the results. And we basically are of the opinion that implementations of Bayh-Dole--that may prevent industry sponsors from securing non-exclusive, royalty-free access to IP--that very research they sponsor will deny industrial sponsors access to what they believe they paid for, and will lead to more conflict between universities and industry.

▪ Bayh-Dole should be applied in cases where the federal government is the sole research sponsor. That's the case for which Bayh-Dole was crafted. When the government is less than the sole research sponsor, then we believe there may be a need for some other means, as far as protecting the interests of private sponsors.

▪ Negotiation delays or those start-up delays in getting a contract in place can be very significant as far as a disadvantage to time to market. And that can make or break a product.

U.S. Government

▪ In short, it is clear that the wealth of nations is changing. While prior centuries were dominated by nations with superior industrial or agricultural capabilities, the Information Age is going to reward new competencies and strengths. Innovative capacity is now clearly the key driver of future national prosperity.

▪ First, we believe we need to better understand the unprecedented global competition for research and innovators. A lot has changed since 1980, not just universities and labs and others better understanding Bayh-Dole. The Cold War is over, and a lot of the global realities and opportunities for business have changed. American innovators are moving cutting-edge research offshore to foreign labs and universities that offer newer facilities, lower costs, highly talented people, and/or simpler and more favorable intellectual property arrangements.

▪ One of our problems is that we are not really able to cogently explain what we do.

▪ I would urge you to make important discriminating points between agencies, type of funding, type of subject matter. I think it's a giant mistake to have a report about technology transfer that compares and pushes together NIH and federal labs. They are different. You should just deal with them as different subjects, and have different recommendations for each one.

▪ Complexity is the enemy of execution. To the extent that you have problems in the implementation of technology transfer, most of them are either a function of misalignment between agency mission, or people who don't understand what they are doing, because the laws and regulations are too complicated. One solution to that is to try and align agency missions and management accountability around technology transfer, and have metrics that apply to individual senior managers, including cabinet secretaries. They tend not to be around very long, but at least they are senior managers.

▪ The biggest challenge of the federal government today is how do you do technology transfer in a new cabinet level department? Stated another way, what kind of biodefense industry or counterterrorism measure industry do we want or deserve in the United States?

No one has asked or effectively answered that question.

We determine whether to seek intellectual property protection on basically five criteria. And these include first of all, the scope of the invention and the market size. And again, in agriculture we are dealing with a lot of small, narrow-margin operations.

The degree of commercial interest is the second criterion. The degree of additional research and development that is necessary to commercialize this technology. Enforceability of the idea. Is this a process that no one is going to be able to determine whether or not you have used this technology?

And the final criterion that we deem to be probably the most important, and that is whether intellectual property protection is necessary to transfer the technology. If it isn't, we're not going to waste our time with it. We are going to make the public release.

▪ Venture capital has seemed to have dried up. We do preferentially license to small businesses. They are risk takers. They need that capital influx typically to move things forward. And that has had an impact this past year.

▪ Lack of a profitable market. We have some terrific solutions to some of the environmental pollution or environmental remediation problems of this century. We researched these for public good. But in the absence of mandatory compliance, there is no marketplace to profitably apply the technologies.

▪ Lack of authority to protect, and therefore to manage distribution. The issue is software, and the fact that we are prohibited from copyrighting and licensing federally developed software… Patents aren't appropriate, because they are too costly, and they are 20 years of exclusivity that really exceeds the useful life of rapidly evolving software technology. Yet, without our ability to copyright and license to provide IP protection and exclusivity, companies can't afford to develop and refine the software with the assistance of federal scientists.

Unknown Affiliation

▪ Regarding the start-up phenomenon, and how we see that being the initial vehicle for commercialization of new technology, particularly disruptive or revolutionary technologies. And what we basically see . . . the reason for that is larger companies have a threshold regarding the "make" versus "buy" equation. A lot of times they can't justify the investment it requires to commercialize relatively immature technologies. So they will wait for a start-up company to get the technology to a certain point, and then they will either merge or have a business alliance or develop a relationship, or in some cases, buy the product. So you see that as an incubator-type period for a lot of these technologies. That is generally for revolutionary-type technologies that are not as mature.

You also see another mode where you have more applied research that generally has more industry involvement such as improvements on existing technologies, or extending current technologies to their ultimate limit. And in that particular role, you see a lot more direct commercialization through some of the larger companies, because the research is more applied to their interests, and they can actually justify making the smaller business investment, and commercialize those companies directly.

So I just would like to point out that it's a complex landscape, and there is more than one mode out there as far as how technology gets commercialized.

▪ University research is cheap. Firms do not pay full overhead costs. So even when they come back and pay a second time, I think in many cases that's risk shared. They don't pay until it gets to a certain point.

The second reason to go to universities, and it was raised here, is that university professors often have very specialized knowledge, which is not internal to the firm. So they can't get it somewhere else…. one of the hardest things firms have to deal with in dealing with universities is understanding university culture. And that is one of the real danger signals.

If a firm goes in not understanding the way a university operates, in part this notion of dissemination of knowledge, and the fact that the goals within universities are not simply profits. They are multifaceted. There are many, many goals. If they don't understand that, that is a recipe for disaster in a licensing session.

▪ It suggests some alignment questions. In the private sector, if you are in a business development context, and your CEO says you're supposed to obtain $50 million for out-licensing a portfolio of products, that's your business goal. There are very few people in the federal government who have a similar mission or management objective.

▪ Licensing, or having intellectual property to license is going to vary from industry to industry. So if you just look at the life science industry, the pharmaceutical industry this year will spend $31 billion on research and development. That's a lot of money.

They can't develop all those products, so they have to have an aggressive licensing platform. The impediments are not so much having great technology. It's having money that [will make you] willing to take the risk on the development part of it, because it costs $80 million on average to create a new pharmaceutical product. It is very risky, very expensive, and very few people have the opportunity to do that.

So there is this kind of reverse thing going on, which is small biotechnology companies who might want to out-license their product, put them together, and develop something. They can probably take the roll of the dice once, develop a product, and then try and license it back.

▪ Inventions are all different. They vary individually within a technology area. They vary across technology areas. And it really depends on a number of factors. Those are a couple. In addition, it is a function of how broad a particular patentable invention is that arises in a particular situation.

▪ Education is so important, to train our scientists and our managers not to disclose this stuff incidentally. It can kill the rights and totally torpedo commercialization.

▪ A bill was introduced earlier this year, or maybe it was last year in the Senate. It was to fund SBIR companies to file foreign patent applications. In other words, the cost of the foreign patent applications was seen as a policy issue affecting small companies disproportionately.

And the way it was going to be set up is a fund that the Small Business Administration was going to be accountable for, a revolving fund. That companies could apply for a one-time grant for funds to file their foreign patent applications.

▪ There is another type of conflict of interest. It's organizational conflict of interest, which I would also like to put on the table for you to consider, especially in the context of the need to work rapidly with companies to commercialize and implement results in homeland security programs.

▪ We really need to be looking at this in an international context, because universities, as well as industry, as you pointed out, are really in an international market. And sometimes we are looking at our laws and policies as though we have just a unified domestic market.

▪ Again, coming as an investor and a developer of a technology, we need a market space. Our contemporaries in Europe, they are learning from our mistakes. They are learning from the roadblocks and hurdles that have been put in place in front of the investor or the entrepreneur.

▪ The original language that was in place, which was interpreted very rigorously in its early days, said that unless the product was substantially manufactured in the U.S., it wouldn't be a deal. If it was a foreign company, it wouldn't be a deal.

And what has happened over time is that position has been interpreted a little bit more liberally as to what substantially manufacturing means. And there have been a few cases where they said, okay, it's very obviously a foreign-owned company, a Siemens, that if they are going to make it in the U.S., at least for the first five years or so, it is okay.

But there are still lots of barriers in place for the laboratories to partner with the company when there is some ambiguity over where it's going to be made, and what the ownership of the company is.

Effective Methods

Colleges/Universities

▪ And though people may not always see eye to eye on all matters, I think overall this Bayh-Dole and Stevenson-Wydler framework has been tremendously successful.

▪ Bayh-Dole is working. The statistics all show it.

▪ Another player is the interaction between the community that learns as a whole how to do entrepreneurial activities and technology transfer, and the sources, the universities, federal labs, etc. That is a long process, but it should not be discounted.

▪ In the UK … they bring their companies within the university, and incubate them within [the university], write the business plans, let them use the labs, even put money in them.

▪ Once you have worked it through, it is very easy the second and third time. …It is a learning curve on the part of individual companies as they learn to work with universities, and why they are different than industry. But . . . intelligently crafted agreements can satisfy both sides.

▪ Most of these faculty, or a lot of them, want to go back to the lab and work on something else. So, one of the things that we found is important to get them to cooperate is the possibility of royalty income, some kind of contingent payments, that they are only going to get these funds if it's successful.

▪ Your objective here was best practices within the technology transfer community. One of the things we are seeing in intellectual property management is this idea of mapping, intellectual property mapping, as well as ideation techniques, and those kind of things.

Federal Laboratories

▪ If you take a look at the vehicles that the laboratories have at their disposal, it goes all the way from truly partnering with other groups in terms of how you work, CRADAs being the most common one… More recently, there has been greater interest in so-called work for others agreements… They are a little bit easier I think, for most industries' perspective as an agreement to execute, than a CRADA. And the differences between them are actually rather minor, but those continue to be relatively popular vehicles.

▪ We came up with a clever idea a few years, and approached the legislature about rebating part of our state tax back, and earmarking those dollars for partnering with small companies that needed help. And that has been a marvelously successful program, and it looks like it is probably due to grow in the future.

Licensing has become very popular recently. There have been something on the order of 700 licenses that have been written. There was a difference in terms of how these are done, and this will resonant with a comment some of the other folks have made earlier. Some licenses go to very large companies. Those are relatively straightforward, and they tend to be incremental kinds of technologies… The more revolutionary things, the disruptive technologies typically go to spin out companies.

▪ A handful of years ago a very popular tool in the private sector was so-called technology mining, where they would look for IP that wasn't core to their business, and say, well, there's a way to monetize it.

And although it might be useful for building satellites for the Air Force, we can also build something to control traffic flow or whatever. And they would spin it out, and they would try to monetize that IP.

They still do that on occasion, but there has been a real shift toward another term that Lockheed Martin uses. It's enterprise venturing -- mission-centered venturing is the term that they use. And the idea there is actually more like what a lab like a Los Alamos or a Sandia would do, where you actually try to commercialize IP in a way that it allows you to mature technology back to the benefit of the core mission of that company.

U.S. Government

▪ Protecting IP is essential to achieve technology transfer when one of two things occurs.

First of all, if there remains an expensive development step and/or a requirement for regulatory approval, and that is often the case in the transgenic plant technology, new pesticide, animal disease vaccine. And the private sector licensee has to be able to recover the cost of the development.

And secondly, if it is a niche market, and the economics of development require that only one or a few companies might participate in that market in order to recover the cost of development. Those are the conditions that we will typically use to identify IP to be protected.

▪ There are really two key components to the success in this area [CRADAs]. The first is that we have technology transfer coordinators. These are eight individuals, typically senior scientists who have a lot of experience… They are geographically dispersed… And in essence, these are field intelligence officers. And on a daily basis, they are the ones that are interacting with the federal scientists, with the customers and the stakeholders, with the private sector, and with the industries, and also with the universities. They are the ones that help the scientists identify the appropriate partnerships, and they negotiate the CRADAs.

Unknown Affiliation

▪ There is this conflict of interest statute, and it's something we have that you people in most universities and industry don't have, because we are blessed with inspectors general (IGs). And the IGs whole job is go around looking for somebody to put in jail. And frankly, inventors making money off of their inventions are very good targets, and they know this, and it has happened to people. And those stories get out and spread, and that puts a chill on things like you never saw.

So if you want to find a problem somewhere, it's in the philosophy of being a public servant in the first place, and what that means as far as serving the public, as opposed to even in state universities now. How they aren't violating state conflict of interest laws, I have never been able to figure out.

▪ One of the attractions for our inventors to participate in commercialization of technologies through the start-up company is the opportunity to participate in the wealth creation of the company by being paid … in equity. And I don't know that that exists at the GOGOs.

▪ If you look at it as a process from idea through commercial product, the more continuity you can build between the stages in the process, the more successful you can be. And so the ultimate deliverer of that technology needs to be involved in the program design to avoid these disconnects.

▪ I just recently learned that Canada, in their whole national research structure, they are encouraging all of their researchers to even go out and to create spin-off companies by training them in business, and giving them leave of absence for a couple of years, with the idea that they can come back if it is not successful. Because most companies aren't successful.

Primary Methods

Federal Laboratories

▪ The royalty dollars that come back into the laboratory … But the use of those funds is to reinvest in research back in the laboratory. . . . We earmark them inside of the laboratory, toward technologies that we think we can use to partner with industry to bring in the next generation of technology into the marketplace.

▪ There are sometimes things we just turn loose, period. The times when you don't just turn it loose, period, is where no one will pursue it. It is just turned loose in the open market, because no one would be willing to put in the funds to take it to the next step, because they don't get a competitive advantage over it. So all of those things happen depending on what the technology is, and what's it going to take to make it mature.

▪ We do have an entrepreneurial leave of absence program, where we try to make it possible for our scientists to move out with the technology, an effective way of transferring that technology, and reducing the risk of commercialization.

▪ We provide training tools and education courses on technology transfer. Included in these are explanations of how the federal labs can do technology transfer through use of various mechanisms. And also training about market assessment, the role of state and local organizations in economic development, and the role of venture capital.

▪ We provide the commercialization assistance, a mentoring program to smaller labs…. A lot of the smaller labs do not have the resources necessary, and we wanted to be able to supply that for them if they needed it, and requested it.

U.S. Government

▪ We determine whether to seek intellectual property protection on basically five criteria. And these include, first of all, the scope of the invention and the market size. And again, in agriculture we are dealing with a lot of small, narrow-margin operations.

The degree of commercial interest is the second criterion. The degree of additional research and development that is necessary to commercialize this technology. Enforceability of the idea. Is this a process that no one is going to be able to determine whether or not you have used this technology?

And the final criterion that we deem to be probably the most important, and that is whether intellectual property protection is necessary to transfer the technology. If it isn't, we're not going to waste our time with it. We are going to make the public release.

▪ There are other circumstances where we want some exclusivity, but by field of use. When we've got a technology … we need the flexibility sometimes to be able to give it broadly, and other times to restrict it by field of use, because there are still some developmental costs associated with that. But in many of the cases, if there is not a big cost to get it started, and not a big investment, that's oftentimes in agricultural endeavors, we want to get it as broadly available as possible, so that the taxpayers, who paid the bill for this, reap the greatest benefit.

▪ We prohibit, or I should say we discourage, the use of patent licensing procedures of patenting products that inhibit and deter the research enterprise. So as long as a recipient of funding is using a patented technology and a material for the purposes of not only commercialization, but also getting the product to other researchers, when that is appropriate, we do not discourage that kind of activity.

Unknown Affiliation

▪ From our standpoint we are going to go where the technology is. If we can't get it here in America, we're going across the pond.

Metrics

Colleges/Universities

▪ Do we have insight into how much institutional and university funding goes into that research effort along with the federal funds through cost sharing or direct costs? Do we have any measures of what contribution the institutions themselves might be making to the technology transfer or the discovery of new technology?

▪ The most commonly used metrics apply to the end product. And that has been demonstrated successfully by the Association of University Technology Managers (AUTM) what those end products are. They are disclosures, new patents issues, new licenses and options grants, and start-up companies formed.

But I propose that the metrics for end products do not tell the whole story. You have to look at the precondition what would generate successful technology transfer. And among those are existing and increasing monetary support for research and development, a solid government patent policy, viable university technology transfer policies, an educated faculty that is aware and interested in technology transfer, availability of discretionary funds for those faculty to protect their intellectual property, and finally, the continued involvement of the inventor in the technology transfer process.

Now, it would also be a mistake to use metrics that only consider applied research, because although basic research does not directly lead to inventions, it has a tremendous multiplier effect, which provides the necessarily stimulus for further development and technology transfer.

▪ To be complete, metrics must also look at the goals the government has established for the outcomes of the programs it funds.

▪ When you look at the AUTM data, don't look at averages, look at the distribution across universities. You get a very, very different picture of what is going on. Unfortunately, averages are what people quote, not distribution.

Federal Laboratories

▪ The important metric … is how these partnerships benefit our primary mission. It is not just about generating dollars per se. It's about how do these things that not only help industry, [but also] help the local economy.

Large Corporations

▪ Once we reach an agreement working with universities or national labs, usually those come out very good. So if you just measure the example of technology transfer, those are already negotiated, then I think the result, if you measure the result, it will be very successful. But I think we have to think about those that are non-starters. And as a technology transfer manager, we have to increase the number of opportunities, and decrease the number of non-starters.

▪ We must establish an end-user metric, the ultimate test, and indeed the challenge of all public policy, as well as the patient or consumer or student or citizen who benefits from the system.

U.S. Government

▪ The CRADA bubble of the 1990s demonstrated the mistake of treating all technology transfer efforts as one in the same, as too many folks pursued CRADAs not because they were the right technology transfer tool, but because headquarters or OMB was counting the quantity, the total number of CRADAs.

We've got to measure what we value, and not value what we measure. This is particularly true, because much significant technology transfer occurs among people, when graduate students take their knowledge to industry, or guest researchers work with federal lab scientists. Such exchanges of knowledge and know-how are almost certainly technology transfer, but they are kind of tough to quantify.

▪ I think metrics are critical, but also one needs to use them carefully. And the intermediary metrics, as people have said, are useful, but are only part of the picture. One has to look at the number of patents, the number of licenses, and the perspective of the end result. And so we are trying more and more to look at, not hide, the metrics into better intermediary, but look at them more in the context of the end result. That is, what's improving? In our case, public health. What is getting on the market? What have we licensed? What can develop in clinical trials, and come to the marketplace that will ultimately benefit public health? In the case of pharmaceuticals and biotechnology products that require regulatory approval, of course that's a long process. And so the metrics of how many products are on the market today is only a measure of things that occurred many years ago. So as you know, it's a long process. It's not like making a widget or an engineering area in which there isn't less or no regulatory approval required. So I would favor metrics that do look particularly at the end product, and not focus entirely on a midstream number, like number of patents, number of licenses per se.

▪ Why the focus on the 30 percent of the federal budget that seems ripe for technology transfer. What is the significance of that? The other 70 percent is not ripe?

General Topics

Colleges/Universities

▪ The vast majority of biology-related, molecular biology-related [research], from which the true biotechnology, as opposed to medical device technology transfer comes, is about as basic as you can get.

▪ If you look at what comes out of universities, about three-quarters of it is very, very basic research. One of the issues as an academic that I'm concerned about, your linear model may well fit federal labs, but the feedback loops, and the effects from the technology transfer and the industries back to the researchers is a very critical issue.

▪ [The] definition of technology transfer … that was a process of transferring a technology for a purpose that it was not originally intended …applies perfectly to university inventions. Most inventions coming out of universities, came out of faculty research, where the faculty member was not at all interested in the end product. It's really curiosity or funding-driven research.

Large Corporations

▪ Our ultimate goal for federally funded research is to help U.S. industry compete globally, not just a large company, or not just a small company.

U.S. Nonprofits

▪ Many of the biotechnology start-ups are actually done by the inventor, and they spin out their own companies. They already have the knowledge. The often have the intellectual property rights.

U.S Government

▪ I think from my experience, which includes a lot of technology agencies, the technology transfer has not really focused on applied versus basic research. If you look at the blockbusters, you will probably see most of them come from basic research. I think the point that has been made already is that those distinctions are really hard to make.

Unknown Affiliation

▪ Biotechnology might be different, and someone else can comment on that, but certainly in the engineering/physics kinds of things, most of what happens in industry is development. It is not applied research, never mind basic research.

And so just looking at the raw dollars and saying, well, industry is going to save our bacon is the wrong answer. It's not.

Bibliography

Several attendees of the December 12, 2002, Technology Transfer Forum suggested that it would be useful to have a comprehensive bibliography of technology transfer references, which we have provided here. This list is not necessarily complete, nor have all the papers cited been studied by the authors, but we hope that the requesters and others involved with technology transfer will find it useful.

A

Aaron, E. 1988. "Tapping Into University Technology—Profiting From University Research." High Technology Business, 8(December): 26-8.

Abelson, P. 1991. "Federal Impediments to Scientific Research." Science, 251(Feb.8): 605.

Ableson, P. 1986. "Evolving state-university-industry relations." Science, (24 January): 317.

Acs, Zoltan J. and David B. Audretsch, 1987, "Innovation, Market Structure and Firm Size," Review of Economics and Statistics, 69, 567-75.

Acs, Zoltan J. and David B. Audretsch, 1988, "Innovation in Large and Small Firms: An Empirical Analysis," American Economic Review, 78, 678-90.

Acs, Zoltan J. and David B. Audretsch, 1989, "Patents as a Measure of Innovative Activity, Kyklos, 42:2, 171-180.

Acs, Zoltan J., David B. Audretsch and Maryann P. Feldman, 1992 "Real Effects of Academic Research: Comment", American Economic Review, 82:1, 363-367.

Acs, Zoltan J., David B. Audretsch and Maryann P. Feldman, 1994, "R&D Spillovers and Recipient Firm Size," The Review of Economics and Statistics, 76:2, 336-340.

Addo, T. B. A. and R. J. Schlesinger. 1991. "Database Considerations in a Technology-Transfer Network." Journal of Technology Transfer, 16 (I): 28.

Agrawal, A., and R. Henderson. (2002). "Putting Patents in Context: Exploring Knowledge Transfer from MIT," Management Science, Vol. 48, No. 1, pp. 44-60.

Ahire, S. L., and Ravicahndran, T. (2001, November). An innovation diffusion model of TQM implementation. IEEE Transactions on Engineering Management, 48(4), 445-464.

Akashah, Saed E. 1987. "Innovation versus the transfer of technology: a case study of R&D in a petroleum-producing country." International Journal of Technology Management, 2(2): 249-62.

Albernathy, W.J. and B.S. Chakravarthy, 1979. "Government Intervention and Innovation in Industry: A Policy Framework," Sloan Management Review. (Spring): 3-18.

Aldhous, P. 1994. "An Industry-Friendly Science Policy." Science, 265(July 29): 596-8.

Alien, T. J. 1966. "The Performance of Information Channels in the Transfer of Technology." Review, 8(1): 87-98.

Alien, T. J., J. Utterback, M. A. Sirbu, and J. H. Holloman. 1978. "Government Influence on the Process of Innovation in Europe and Japan." Research Policy, 7: 124-129.

Alien, T., D. Hyman, and D. Pinckney 1983. "Transferring technology to the small manufacturing firms: A study of technology transfer in three countries." Research Policy, 12.

Ambrosio, E. M. 1995. "Technological Management And Transfer of Technology." International Journal of Technology Management, 10(7-8): 665-675.

Anderson, C. 1993. "Rocky Road for Federal Research Inc." Science, 262(October 22): 496-8.

Aneja, A.P. and Aneja, V.P., "The Strategy of Process Translation," Vol. 20, No.6, November, 1977, pp. 37-40

Anselin L., A. Varga and Z. Acs 1997. "Local geographic spillovers between university research and high technology innovations." Journal of Urban Economics 42(3): 422-448.

Arbaugh, J. B. & D. L. Sexton. 1995. "Assessing Present Practices for Defense Conversion in Small to Medium-Sized Firms." Journal of Technology Transfer, 20(1): 84.

Ardis, M. A. , & Marcolin, B. L. (2001). "Diffusing software product and process innovations (Proceedings of the IFIP TC8 WG8.6 fourth working conference on diffusing software product and process innovations)" , Banff, Canada, Kluwer Academic Press, Boston.

Argote, L., S. Beckman., D. Epple 1990. "The persistence and transfer of learning in industrial settings" Management Science, 36(2).

Armbrecht R.F.M, Chapas R.B., Chappelow C.C., Farris G.F., Friga P.N., Hartz C.A., Mcllvaine M.E., Postale S.R., and Whitwell G.E., "Knowledge Management in R&D," Vol. 44, No. 4, July-August 2001, pp. 28

Armstrong, J. A. 1993. "University-Research--New Goals, New Practices." Issues in Science and Technology, 9(2): 50-53.

Association of American Universities 1986. Trends in Technology Transfer at Universities: Report of the Clearinghouse on University-Industry Relations. (Washington, DC).

Association of University Technology Managers (AUTM) Licensing Survey: FY2000 (Northbrook Illinois, 2001).

Atkinson, R. 1991. "Innovation Policy Making in a Federalist System: Lessons from the States for US Federal Innovation Policy Making." Research Policy, 20(6): 559.

Attewell, P. (1992, February). Technology diffusion and organizational learning: The case of business computing. Organization Science, 3(1), 1-19.

Audretsch, D.B. and M. Vivarelli 1996. "Firms size and R&D spillovers: Evidence from Italy." Small Business Economics, 8(3): 249-258.

Audretsch, D.B. and M.P. Feldman, 1996, "R&D Spillovers and the Geography of Innovation and Production," American Economic Review, 86:3, 630-640.

Audretsch, David, Barry Bozeman, Kathryn Combs, Maryann Feldman, Albert Link, Donald Siegel, Paula Stephan, Gregory Tassey and Charles Wessner, 2002, "The Economics of Science and Technology," Journal of Technology Transfer, 27, 155-203.

Autio E. and A. P. Hameri 1995. "The structure and dynamics of technological systems: A conceptual model." Technology in Society, 17(4): 365-384.

Autio, E. 1997. New technology-based firms in innovation networks: Sympletis and generative impacts." Research Policy, 26(3): 263-281.

Autio, E. and T. Laamanen 1995. "Measurement and Evaluation of Technology-Transfer--Review of Technology-Transfer Mechanisms and Indicators." International Journal of Technology Management, 10(7-8): 643-664.

Ayres, R. U. 1986. "Technological Protection and Piracy: Some Implications for Policy." Technological Forecasting and Social Change, 30(1): 5-19.

Ayres, R.U., 1985. "A Schumpeterian Model of Technological Substitution," Technological Forecasting and Social Change, 27(4): 375-385.

Azzone G. and P. Maccarrone 1997. "The emerging role of lean infrastructures in technology transfer: the case of the Innovation Plaza project." Technovation, 17(7): 391-402.

B

Backer, T. E 1995. "Assessing and Enhancing Readiness for Change - Implications for Technology Transfer." NIDA Research Monograph, 155: 21.

Backer, T. E. & S. L. David 1995. "Synthesis of Behavioral Science Learnings About Technology Transfer." NIDA Research Monograph, 155: 262.

Bagur, J., and Guissinger, A. 1987. "Technology transfer legislation: An overview." Journal of Technology Transfer. 12:51-63.

Baker, J. “Creating Knowledge Creating Wealth: Realising the Economic Potential of Public Sector Research Establishments.” A report by John Baker to the Minister for Science and the Financial Secretary to the Treasury, August 1999. (http://www.hm-treasury.gov.uk/Documents/Enterprise_and_Productivity/Research_and_Enterprise/ent_sme_baker.cfm)

Balachandra, R. 1996. "International technology transfer in small business: A new paradigm." International Journal of Technology Management, 12(5-6): 625-638.

Barnes, A. D., ed. 1987. Technology Transfer: A European Perspective. (Sheffield: University of Sheffield).

Baron, Seymour, "Overcoming Barriers to Technology Transfer," Vol. 33, No. 1,January-February, 1990, pp. 38-43

Bartlem, C. S., and Locke, E. A. (1981, July). The Coch and French study: a critique and reinterpretation. Human Relations, 34(7), 555-566.

Baruch, J. J. 1990. "Transferring Technology into and within the Third World." Journal of Technology Transfer, 15(3): 29.

Basalla, G. 1967. "The Spread of Western Science." Science, 156(May): 611-622.

Basalla, G. 1993. "The Spread of Western Science Revisited." In Mundializacion de la Ciencia y Cultura Nacional. A. Elena and M. L. Ortega (eds.) (Madrid: Ediciones Doce Calles).

Bayer, J., & Melone, N. (1988, August). "Adoption of software engineering innovations in organizations." (CMU/SEI-88-TR-27). Software Engineering Institute, Pittsburgh, PA.

Bayer, J., and Melone, N. (1989, February). A critique of diffusion theory as a managerial framework for understanding adoption of software engineering innovations. Journal of Systems & Software, 9(2), 161-166.

Beaumont, C., J. Dingle and A. Reithinger. 1981. "Technology Transfer and Applications." R & D Management, 11: 149-156.

Beecham, M. A. and M. Cordey-Hayes 1998. "Partnering and knowledge transfer in the UK motor industry." Technovation, 18(3): 191-205.

Benowitz, S. “Hard Choices,” The Scientist, 9[18], September 18, 1995.

Berkowitz, B. D. 1992/1993. "Can Defense Research Revive US Industry?" Issues in Science and Technology, 9(Winter): 73-81.

Berkowitz, B. D. 1994. "Why defense reinvestment won't work--President Clinton wants to stimulate the economy by adapting defense firms to civilian manufacturing, a task for which they are not at all suited." Technology Review, 97(July): 52-60.

Berman, E. 1990. "R&D Consortia - Impact on Competitiveness?" Journal of Technology Transfer, 15(3): 5.

Berman, E. M. 1990. "The economic impact of industry-funded university R&D." Research Policy, 19: 349-355.

Berman, E. M. 1994. "Technology Transfer And The Federal Laboratories--Midterm Assessment Of Cooperative Research" (Part Of A Symposium On Technology Transfer And Public Policy). Policy Studies Journal, 22(2): 338-348.

Berman, E. M. 1994. "Technology-Transfer And The Federal Laboratories - A Midterm Assessment Of Cooperative Research." Policy Studies Journal, 22(2): 338-348.

Berniker, E. 1991. “Models of technology transfer: a dialectical case study.” Proceedings of the IEEE Conference: The New International Language, July, pp 499-502.

Bertha, S. L. 1990. "Technology Contracts - An Academic Perspective." Journal of Technology Transfer, 15(1 & 2): 41.

Bessant, J. and H. Rush 1995 "Building Bridges For Innovation: The Role Of Consultants In Technology Transfer." Research Policy, 24(1): 97-115.

Betz, F. 1994. "Basic Research And Technology-Transfer." International Journal of Technology Management, 9(5-7): 784-796.

Bidault, F. and W. A. Fischer 1994. "Technology Transactions--Networks Over Markets." R&D Management, 24(4): 373-386.

Bijker, W. E., Hughes, T. P., & Pinch, T. J. (Eds.). (1987). "The social construction of technological systems: New directions in the sociology and history of technology." MIT Press, Cambridge, MA.

Billups, J. 0. and M. C. Julia 1996. "Technology transfer and integrated social development: International issues and possibilities for social work." Journal Of Sociology And Social Welfare, 23(1): 175-188.

Bishop, A. P. & M. B. Peterson. 1990. "Developing Information Systems for Technology Transfer: An Example from Tribology." Science & Technology Libraries, 11(2): 5.

Blanchard, P.A. and C. McDonald 1986. "Reviving the spirit of enterprise role of the federal labs." Physics Today, 39: 42-50.

Blasberg, B.L. 1987. "Patents and the Measurement of Technological Change: A survey of the literature." Research Policy, 16(2-4): 131.

Bloch, E. 1994. "Updated Science Policy-Making--Finishing The Job. Issues in Science and Technology, 11(1): 22-26.

Bloch, E. and D. Cheney 1993. "Technology Policy Comes Of Age." Issues in Science and Technology, 9(4); 55-60.

Blumenthal, D., S. Epstein and J. Maxwell, J. 1986. "Commercializing university research - lessons from the experience of the Wisconsin Alumni Research Foundation." New England Journal of Medicine, 3214(25): 1621-1626.

Bodelle, Jacques and Jablon, Claude, "Science and Technology Scouting at Elf Aquitaine," Research-Technology Management, Vol. 36, No. 5, September-October, 1993, pp. 24-28

Bonomo, J., J. Lowell, J. Finder, K. Webb, J. Saul, P. Cannon, J. Sloan and D. M. Adamson 1998. Monitoring and Controlling the International Transfer of Technology. (Santa Monica, CA: RAND, Critical Technologies Institute).

Bostrom, R. P., and Heinen, J. S. (1977, September). MIS problems and failures: A socio-technical perspective, part I: the causes. MIS Quarterly, 1(3), 17-32.

Boulton, W., M. Dowling and J. Lohmeyer 1992. "Technology Development Strategies in Japan, Europe and the United States." Technovation 12(2): 99.

Bozeman, B. 1994. "Evaluating Government Technology Transfer: Early Impacts of ‘Cooperative Technology' Paradigm." Policy Studies Journal, 22(2): 322-337.

Bozeman, B. and A. Link. 1985. "Public Support for Private R&D: The Case of the Joint Venture Research Tax Credit." Journal of Policy Analysis and Management, 4 (3): 370-382.

Bozeman, B. and D. Rahm. 1989. "Science and Technology Consequences for Public Management," in Handbook of Public Administration, ed. J. Perry (San Francisco, CA: Jossey-Bass).

Bozeman, B. and E. Cole. 1982. "Scientific Information Acquisition in Public Agencies: The Role of Channel Preference and 'Gatekeeping'." Administration and Society, September.

Bozeman, B. and F. Rossini. 1977. "National Strategies for Technological Innovations." Administration and Society, 9(1): 81-111.

Bozeman, B. and J. L. Bozeman 1990." Technology-Intensive Business Views of Government's Role: Implications for Economic Development." Policy Studies Review.

Bozeman, B. and K. Coker 1992. "Assessing the Effectiveness of Technology Transfer from US Government R&D Laboratories: The Impact of Market Orientation." Technovation 12(4): 239.

Bozeman, B. and M. Crow 1988. "US R&D Laboratories and their Environments: Public and Market Influence." Final Report to the National Science Foundation, Science Resources Section. (Syracuse, NY: Technology and Information Policy Program).

Bozeman, B. and M. Crow 1991. "Red Tape and Technology Transfer in Government Labs in the US." Journal of Technology Transfer 16(2): 29.

Bozeman, B. and M. Crow 1991. "Technology Transfer from US Government and University R&D Laboratories." Technovation 11(4): 231.

Bozeman, B. and M. Fellows 1988. "Technology Transfer at the US National Laboratories, A Framework for Evaluation." Evaluation and Program Planning, 11(1): 65-75.

Bozeman, B. and R. McGowan. 1982. "Information Acquisition and Political Environments in Technologically - Intensive Government Agencies," in The Transfer and Utilization of Technical Knowledge. ed. D. Sahal (Lexington, MA: Lexington Books).

Bozeman, B. and S. Pandey. 1994. "Cooperative R&D in Government Laboratories: Comparing the US and Japan" Technovation, 14(3): 145-215.

Bozeman, B., A. Link and A. Zardkoohi. 1987. "An Economic Analysis of R&D Joint Ventures." Managerial and Decision Economics.

Bozeman, B., D. Rahm, and M. Crow 1987. "Technology Transfer to Government and Industry: Who? Why? And to What Effect?" Paper presented at the Harvard Business School Colloquium on Operations and Production.

Bradbury, Frank (ed.) 1978. Transfer processes in technical change. (Alphen annden Rijn, Netherlands: Sijthoff and Noordhoff.)

Branscomb, L. M. 1992. "America's Emerging Technology Policy." Minerva, 30(3): 317-336.

Branscomb, L., R. Florida, D. Hart, J. Keller and D. Boville 1997. "Investing in Innovation, Toward a Consensus Strategy for Federal Technology Policy, http://www.ksg.harvard.edu/iip/techproj/invest.html

Brenner M.S. and Tao J.C., "You Can Measure External Research Programs," Vol, 44. No. 3, May-June 2001, pp 14-15

Bretschneider, S. and B. Bozeman. 1986. "Adaptive Diffusion Models for the Growth of Robotics in New York State Industry." Technological Forecasting and Social Change, 30(2): 111-123.

Brockhoff, K. and T. Teichert 1995. "Cooperative Research-And-Development And Partners Measures Of Success." International Journal of Technology Management, 10(1): 111-123.

Brooks, H. 1994. "The Relationship Between Science and Technology." Research Policy, 23 (5): 477-487.

Brown M. A. 1997. "Performance metrics for a technology commercialization program." International Journal of Technology Management, 13(3): 229-244.

Brown M. A. and C. R. Wilson 1992. "Promoting The Commercialization Of Energy Innovations - An Evaluation Of The Energy-Related Inventions Program." Policy Studies Journal, 20(1): 87-101.

Brown, G. E. 1994. "New Ways Of Looking At US Science And Technology." Physics Today, 47(September): 31-5.

Brown, M. A. 1990. "The cost of commercializing energy inventions." Research Policy, 19: 147-155.

Brown, M. A. and C. H. Major. 1990. "Technology Transfer Strategies of DOE'S Conservation Programs." Journal of Technology Transfer, 15(1-2): 33.

Brown, M. A., T. R. Curlee and S. R. Elliott. 1995. "Evaluating Technology Innovation Programs: The Use of Comparison Groups to Identify Impacts." Research Policy, 24(5): 669-685.

Brown, M., L. Berry and R. Goel. 1991. "Guidelines for Successfully Transferring Government-Sponsored Innovations." Research Policy, 20(2): 109.

Buchan, R. L. 1990. "Technology Transfer at NASA --A Librarian's View." Science & Technology Libraries, 11(2): 49.

Buckley, P. J. 1997. "International technology transfer by small and medium-sized enterprises." Small Business Economics, 9(1): 67-78.

Burrell, G., and Morgan, G. (1979). "Sociological paradigms and organizational analysis." Heinemann, Portsmouth, NH.

Busch, V.J. "Combinatorial Analysis-How Much Is It Worth?", Vol. 44, No. 2,March-April, 2001, pp. 38-39

Butler, B., & Gibbons, D. (1998). Power distribution as a catalyst and consequence of decentralized diffusion. In "Information systems innovation and diffusion: issues and directions" (T. J. Larsen, and E. McGuire, Eds.), pp. 3-28. Idea, Hershey, PA.

Buxton, J. N., and Malcolm, R. (1991, January). Software technology transfer. Software Engineering Journal, 6(1), 17-23.

Byrd, T. A. , and Marshall, T. E. (1997). Relating information technology investment to organizational performance: A causal model analysis. Omega, International Journal of Management Science, 25(1), 43-56.

C

Cale, E. G. , and Curely, K. F. (1987). Measuring implementation outcome: Beyond success and failure. Information & Management, 13(5), 245-253.

California Department of Commerce, 1987. Technology transfer: the California experience. (Sacramento, CA: California Department of Commerce; Office of Economic Research.)

Cameron, H.M., and J. S. Metcalfe 1987. "On the Economics of Technological Substitution." Technological Forecasting and Social Change, 32 (2): 147.

Caputo, K. (1998). "CMM implementation guide: Choreographing software process improvement." Addison-Wesley, Reading, MA.

Carr, R. K. "Doing Federal Technology Transfer (Part I). 1992." Journal of Technology Transfer, 17 (2 & 3): 8.

Carr, R. K. 1992. "Menu of Best Practices (Part 2)." Journal of Technology Transfer, 17 (2 & 3): 24.

Carr, R.K., “Menu of Best Practices in Technology Transfer,” Journal of Technology Transfer, 17 No. 2/3, pp. 24-33 (1992). (http://www.millkern.com/rkcarr/flpart2.html)

Casey, W.J., “Technology Exchange with the USSR," Vol. 17, No. 4, July, 1974,pp. 7-9

Caswell, M. and R. Shoemaker 1997. "Agricultural policies to encourage the diffusion of environmentally preferred technologies." American Journal Of Agricultural Economics, 79(5): 1730-1730.

Chaddha, R. L., and Chitgopekar, S. S. (1971, Autumn). A "generalization" of the logistic curves and long-range forecasts (1966-1991) of residence telephones. Bell Journal of Economics, 2 (2), pp. 542-560.

Chakrabarti, A. K. , I. Dror and N. Eakabuse 1993. "Interorganizational Transfer Of Knowledge--An Analysis Of Patent Citations Of A Defense Firm." IEEE Transactions On Engineering Management, 40(1): 91-94.

Chakrabarti, A.K. 1973. "Some concepts of technology transfer: Adoption of innovations in organizational context." R&D Management. 3 (3).

Chakrabarti, A.K. and Rubenstein, A.H. 1975. "Interorganizational transfer of technology: Adoption of NASA innovations." IEEE on Transactions on Engineering Management. EM-23, (I): 20-34.

Chalk, R. and P. Woolf. 1988-89. "Regulating a 'Knowledge Business'." Issues in Science & Technology, 5(2): 33-37.

Chang P. L., C. Shih and C. W. Hsu 1994. "The Formation Process Of Taiwan IC Industry - Method Of Technology-Transfer." Technovation, 14(3): 161-171.

Chapman, R. 1991. "Selling the Technology-Transfer Function." Journal of Technology Transfer, 16 (3): 8.

Chapman, R.L. 1986. "The uncounted benefits: Federal efforts in domestic technology transfer." Technology Transfer Society International Symposium Proceedings 1986.

Charles, D., J. Howells and S. R. Postle 1993. "Technology Transfer In Europe--Private And Public Networks." R&D Management, 23(3): 269-270.

Chau, P. Y. K., and Tam, K. Y. (1997, March). Factors affecting the adoption of open systems: An exploratory study. MIS Quarterly, 21(1), 1-20.

Checkland, P. (1993/1999). "Systems thinking, systems practice." (30-year retrospective) John Wiley & Sons, West Sussex, England.

Checkland, P., & Scholes, J. (1990/1999). "Soft systems methodology in action." (30-year retrospective) John Wiley & Sons, West Sussex, England.

Chiang, J. 1991. "From Mission-Oriented to Diffusion-Oriented Paradigm: The New Trend of US Industrial Technology Policy." Technovation, 11(6): 339.

Chiang, J. T. 1995. "Technology Policy Paradigms And Intellectual Property Strategies: Three National Models." Technological Forecasting And Social Change, 49(1): 35-49.

Chiasson, M. W., and Lovato, C. Y. (2001, Summer). Factors influencing the formation of a user's perceptions and use of a DSS software innovation. Data Base for Advances in Information Systems, 32(3), 16-35.

Chiesa, V. and R. Manzini 1996. "Managing knowledge transfer within multinational firms." International Journal of Technology Management, 12(4): 462-476.

Chifos C. and R. K. Jain 1997. "A comprehensive methodology for evaluating the commercial potential of technologies: The strategic technology evaluation method." International Journal Of Industrial Engineering-Applications And Practice,(4): 220-235.

Christensen, Clayton M. The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. Harper Books, New York, 1997.

Christensen, C. M. and R. S. Rosenbloom. 1995. "Explaining the Attacker's Advantage: Technological Paradigms, Organizational Dynamics and the Value Network." Research Policy, 24(2): 207-233.

Clark, W. W. 1995. "Sharing American and European Economic Experiences in Technology Conversion." Journal of Technology Transfer, 20(1): 9.

Clarke, R. 1985. Science and Technology in World Development. (Oxford: Oxford University Press).

Climent, J. B., C. Palmer, S. Ruiz. 1995. "Omissions Relevant to the Contextual Domains of Technology Transfer Models." Journal of Technology Transfer, 20 (I): 93.

Cobb, S. L. & T. S. Barker. 1992. "A Model of Cross-Cultural Training in the Transfer of Technology." Journal of Technology Transfer, 17 (4): 8.

Coch, L., and French, J. R. P. (1948). "Overcoming resistance to change." Human Relations, 1(4), 512-532.

Cohen, Hirsh, Keller, Seymour and Streeter, Donald, "The Transfer of Technology from Research to Development," Vol. 22, No. 3, May, 1979, pp. 11-17

Cohen, M. D., March, J. G., and Olsen, J. (1972, March). A garbage can model of organizational choice. Administrative Science Quarterly, 17(1), 1-25.

Cohen, W.M. and D.A. Levinthal, 1989, "Innovation and Learning: the Two Faces of R&D," The Economic Journal, 99:397, 569-596.

Cohn, S.F., "Adopting Innovations in a Technology Push Industry," Vol. 24, No.5, September, 1981, pp. 26-31

Colton, R. 1987. "University/Industry Cooperative Research Centers Are Proving Themselves." Research Management, 30(2): 34-38.

Colton, R. M. 1985. "Status Report on the NSF University/Industry Cooperative Research Centers." Research Management, 28(6): 25-32.

Colyvas, Jeannette, Michael Crow, Annetine Gelijns, Roberto Mazzoleni, Richard Nelson, Nathan Rosenberg, and Bhaven Sampat. 2001. "How Do University Inventions Get Into Practice?" Management Science 48: 61-72.

Comer, J.M., O'Keefe, R.D. and Chilenska, A.A. 1980. "Technology transfer from government laboratories to industrial markets." Industrial Marketing Management, 9: 63-67.

Conceicao P., M. V. Heitor and P. Oliveira 1998. "University-based technology licensing in the knowledge based economy." Technovation, 18(10): 615-625.

Conflicts Of Interest In University Technology Transfer." 1991. Chemtech, 21(February): 72-3.

Conner, D. (1993). "Managing at the speed of change: How resilient managers succeed and prosper where others fail." Villard Books, New York, NY.

Conn-Farkas, I. 1988. "Human aspects of information management for technology transfer." Information Management Review. 4: 47-56.

Contractor, F. J. and Sagafi-Nejad, T. 1981. "International technology transfer: Major issues and policy responses." Journal of International Business Studies, (Fall): 113-135.

Cooper, R. B., and Zmud, R. W. (1990, February). Information technology implementation research: A technological diffusion approach. Management Science, 36(2), 123-139.

Cordell, A J and J Gilmour. 1976. The Role and Function of Government Laboratories and the Transfer of Technology to the Manufacturing Sector. Science Council of Canada. (Oshawa: Marade Press).

Correa, C. M. 1994. "Trends in technology transfer – implications for developing countries." Science & Public Policy, 21 (6): 369.

Correa, C. M. 1995. "Innovation And Technology-Transfer In Latin America - A Review Of Recent Trends And Policies." International Journal of Technology Management 10(7-8): 815-846.

Correa, C. M. 1998. "Argentina's national innovation system." International Journal of Technology Management, 15(6-7): 721-760.

Coursey, D. and B. Bozeman 1992. "Technology-Transfer In United States Government And University Laboratories--Advantages And Disadvantages For Participating Laboratories." IEEE Transactions on Engineering Management, 39(4): 347-351.

Courtial, J. P. and A. Sigogneau 1995. "How To Use Scientific And Technological Information To Reveal Strategic Technologies." International Journal of Technology Management, 10(1): 31-44.

Cowan, R. and D. Forays. 1995. "Quandaries in the Economics of Dual Technological and Spillovers from Military to Civilian Research and Development." Research Policy, 24(6): 851-869.

Cowger, G. L. 1992. "Teaming for National Competitiveness." Journal of Technology Transfer, 17 (2 & 3): 34.

Crow, M. 1985. "The Effect of Publicness on Organizational Performance: A Comparative Study of R&D Laboratories." (Ph.D. Dissertation, Syracuse University).

Crow, M. 1989. "Technology and Knowledge Transfer in Energy R&D Laboratories: An Analysis of Effectiveness." Evaluation and Program Planning.

Crow, M. 1989. "Technology Development Strategies: Assessing the Effect of Government Influence on Industrial Research and Development." Research Management.

Crow, M. and B. Bozeman 1990. "Federal Laboratories: Information Products and Policies." in Perspectives on US Government Scientific and Technological Information Policies. eds. C. McClure and P. Hernon (Norwood, NJ: Ablex Publishing).

Crow, M. and B. Bozeman 1998. Limited by design: R&D laboratories in the U.S. national innovation system. (New York: Columbia University Press).

Crow, M. and B. Bozeman. 1987. "A New Typology for R&D Laboratories: Implications for Policy Analysis." Journal of Policy Analysis and Management, 6 (3): 328-341.

Crow, M. and B. Bozeman. 1987. "R&D Laboratories Environmental Contexts: Are the Government Lab-Industrial Lab Stereotypes Still Valid?" Research Policy, 13(December):329-355.

Crow, M. and M Emmert. 1987. "Organized Science and Public-Private Cooperation." Journal of Management, 13(1): 55-67.

Crow, M. and M. Emmert. forthcoming. "Public, Private and Hybrid Organizations: An Empirical Examination of the Role of Publicness." Administration and Society.

Crow, M. and S. Nath. 1990. "Technology Strategy Development in Japanese Industry: An Assessment of Market and Government Influences." Technovation, 10(5): 333.

Crow, M. and S. Nath. 1992. "Technology Strategy Development in Korean Industry: An Assessment of Market and Government Influences." Technovation, 12(2): 119.

Crow, M., B. Bozeman, W. Meyer and R. Shangraw. 1988. Synthetic Fuel Technology Development in the United States. (New York: Praeger).

Crow, M., W. Lambright, and R. Shangraw. 1984. "National Projects in Civilian Technology." Policy Studies Review, 2(3-4): 453-459.

Cusumano M. A. and D. Elenkov 1994. "Linking International Technology-Transfer With Strategy And Management --A Literature Commentary." Research Policy, 23(2): 195-215.

Cutler, R. 1988. "Survey of high-technology-transfer mechanisms in Japan and the USA." Technology Transfer. 42-48.

Cutler, W.G., "Acquiring Technology From Outside," Vol. 34, No. 3, May-June, 1991, pp. 11-18

Cyert, R M. 1985. "Establishing University-Industry Joint Ventures. Research Management, 28(1): 27-29.

D

Dahlstrand A. L. "Growth and inventiveness in technology-based spin-off firms." Research Policy, 26(3): 331-344.

Daipe, R., C. DeBresson, and H. Xiaoping. 1992. "The Public Sector as First User of Innovations." Research Policy, 21(3): 251.

Dakin, K. 1994. "BodyShock - A Technology Transfer Opportunity." Journal of Technology Transfer, 19 (2): 47.

Dalton, D. H. and M. G. Serapio, Jr. 1995. Globalizing Industrial Research and Development. (Department of Commerce, Office of Technology Policy, Asia-Pacific Technology Program).

Daniels, F. 1994. "University-Related Science Parks-Seedbeds or Enclaves of Innovation?" Technovation, 14(2):93-39.

Daniels, P. L. 1997. "National technology gaps and trade – An empirical study of the influence of globalisation." Research Policy, 25(8): 1189-1207.

David Jr., E.E., "Technology Export and National Goals," Vol. 17, No. 1, January, 1974, pp.12-16

David, P. A. 1986. "Technology diffusion, public policy, and industrial competitiveness." in The Positive Sum Strategy: Harnessing Technology for Economic Growth. R. Landau and N. Rosenberg (eds.) (Washington, DC: National Academy Press): 373-391.

Davidson, W. 1983. "Structure and performance in international technology transfer." Journal of Management Studies, 20: 453-465.

Davidson, W. and D. G. McFetridge 1985. "Key characteristics in the choice of international technology transfer mode." Journal of International Business Studies, (Summer): 5-21.

Davies, H. 1977. "Technology transfer through commercial transactions and the theory of the firm." Journal of Industrial Economics, 26: 161-175.

Davis, S. 1979. The Diffusion of Process Innovations. (Cambridge, England: Cambridge University Press).

De Bruijn, E.J. and Jia, Xianfeng, "Transferring Technology to China by Means of Joint Ventures," Vol. 36, No. 1, January-February, 1993, pp. 17-22

De la Barre, D.M. 1985. "Federal technology transfer act of 1985: PL99-502 at a glance." The Journal of Technology Transfer, 2 (1).

Dearaujo, J. L. 1995. "Are Technology Diffusion-Processes Inherently Historical." Technological Forecasting and Social Change, 48(3): 243-257.

DeBondt, R. 1997, "Spillovers and innovative activities." International Journal Of Industrial Organization, 15(1): 1-28.

DeCanio, S. J., Dibble, C., and Amir-Atefi, K. (2000, October). The importance of organizational structure for the adoption of innovations. Management Science, 46(10), 1285-1299.

Dechenaux, Emmanuel, Brent Goldfarb, Scott Shane and Marie Thursby, 2002. "Appropriability and the timing of innovation: Evidence from MIT inventions," unpublished paper, July. 3.

Delamothe, J. and P. R. Dufour 1995. "Techno-Globalism And The Challenges To Science And Technology Policy." Daedalus, 124(3): 219-235.

Dembo, V. 1979. "Technology transfer planning" in R&D Management. 9(3).

Denny, J. E. 1983. "Cooperative R&D: DOE'S Patent Policy Need Not be a Barrier." Research Management, 34-39.

Dent, E. B., and Goldberg, S. G. (1999, March). Challenging "resistance to change". Journal of Applied Behavioral Science, 35(1), 25-41.

DesForges, C. D. 1986. "US and UK experience in technology transfer: a comparative analysis." International Journal of Technology Management, 1(3-4): 457-476.

Detragiache, E. 1998. "Technology diffusion and international income convergence." Journal of Development Economics, 56(2): 367-392.

Devine, M., James, T., & Adams, T. 1987. "Government supported industry-university research centers: issues for successful technology transfer." Journal of Technology Transfer. 12:27-37.

Diamond, M. A. (1986, September). Resistance to change: A psychoanalytic critique of Argyris and Schon's contributions to organization theory and intervention. Journal of Management Studies, 23(5), 543-562.

Dietrich, J.J., & Sen, R.K. 1981. "Making industry-university-government collaboration work." Research Management. 23-25.

Dill, D. 1990. "University/Industry Research Collaborations: An Analysis of Interorganizational Relationships." R&D Management 20(2): 123.

Dill, D. D. 1995. "University-Industry Entrepreneurship – The Organization And Management Of American-University Technology-Transfer Units." Higher Education, 29(4): 369-384.

DiMaggio, P. J., and Powell, W. W. (April 1983). The Iron Cage revisited: Institutional isomorphism and collective rationality in organizational fields. American Sociological Review, 48(2), 147-160.

Doctors, S. I. 1969. The Role of Federal Agencies in Technology Transfer. (Cambridge: MIT Press).

Doctors, S. I. 1971. The NASA Technology Transfer Program.(New York: Praeser).

Doelling, N. 1982. "Sea grant-The MIT sea grant marine industry collegium: A partnership of industry, government and academia." Journal of Technology Transfer. 6 (2): 9.

Doms, M. E & R. H. McGuckin. 1992. "Trade in high technology products." Science & Public Policy, 19 (6): 343.

Dorf, R. and K. F. Worthington 1987. "Models for commercialization of technology from universities and research laboratories." Journal of Technology Transfer. 12:1-9.

Dorf, R. and K. Worthington. 1990. "Technology Transfer from Universities and Research Laboratories." Technological Forecasting and Social Change, 37(3): 251-266.

Dorfman, N. S. 1983. "Route 128: The Development of a Regional High Technology Economy." Research Policy, 12(6).

Douds, C.F. 1971. "The state of the art in the study of technology transfer: A brief survey." R&D Management. 1 (June).

Dunning, J.H. 1983. "Market power of the firm and international transfer of technology." International Journal of Industrial Organization, 333-351.

Dupuy D. 1997. "Technological change and environmental policy: The diffusion of environmental technology." Growth and Change, 28(1): 49-66.

E

Eads, G. 1974. "US Governmental Support for Civilian Technology: Economic Theory Versus Political Practice." Research Policy, 3:2-16.

Easterbrook, S. (Ed.). (1992). "CSCW: Cooperation or conflict?" Springer-Verlag, London.

Easton, T. and Parbhoo, B., "Clubs Promote R&D Interaction at Dow Corning," Vol. 41, No. 1, January-February, 1998, pp. 12

Edmunds, A. , and Morris, A. (2000, February). The problem of information overload in business organisations: A review of the literature. International Journal of Information Management, 20(1), 17-28.

Edwards, R. L. 1994. "The Industrial Revitalization Forums Program. Journal of Technology Transfer, 19 (2): 43.

Egide, K. 1984. "Technology Transfer: A look at the federal sector." Journal of Technology Transfer. 9: 71-89.

Eldred, E.W. and McGrath, M.E., Commercializing New Technology - II, Vol.40, No. 2, March-April, 1997, pp. 29-33

Elzen, B., B. Enserink and W. A. Smit 1996. "Sociotechnical Networks--How A Technology Studies Approach May Help To Solve Problems Related To Technical Change." Social Studies Of Science, 26(1): 95-141.

Engel, C. 1990. "The Public Library - A Key to Technology Transfer." Science & Technology Libraries, 11(2): 89.

Enriquez, Juan and Rodrigo Martinez, 2002, "The Bioltechonomy (1.0): A Rough Map of Bio-Data Flow," Harvard Business School Working Paper, 3:028.

Erbisch, F. H. & G. R. Butler. 1991. "Technology Transfer with an Intellectual-Property Focus." Journal of Technology Transfer, 16(1): 41.

Ethier, W. J. and J. R. Markusen 1996. "Multinational firms, technology diffusion and trade." Journal of International Economics 41(1-2): 1-28.

Ettlie, J. 1982. "The commercialization of federally sponsored technological innovations." Research Policy. 11: 173-192.

European Commission 1994. Growth, Competitiveness, Employment: The Challenges and Ways Forward into the 21st Century, white paper. (Luxembourg: Office for Official Publications of the European Communities).

Evans, T.P. 1976. "Triggering technology transfer." Management Review. 26-33.

Ezzat, H.A., Howell, L.J. and Kamal, M.M., "Transferring Technology at General Motors," Vol. 32, No. 2, March-April, 1989, pp. 32-35

F

Fan, M., Stallaert, J., and Whinston, A. B. (2000, March). The adoption and design methodologies of component-based enterprise systems. European Journal of Information Systems, 9(1), 25-35.

Farkas-Conn, I.S. 1988. "Human aspects of information management for technology transfer." Information Management Review. 4 (2).

Faulkner, W. and J. Senker. 1994. "Making Sense of Diversity: Public-Private Sector Research Linkage in Three Technologies." Research Policy, 23(5): 673-697.

Federal Technology Transfer Act of 1986, 99th Congress, 2nd Session.

Federal Technology Transfer Act, 1986. Senate Report 99-283.

Feller I. 1997. "Manufacturing technology centers as components of regional technology infrastructures." Regional Science And Urban Economics, 27(2): 181-197.

Feller, Gordon, "Tapping Soviet/East European Scientific and Technical Prowess," Vol. 33, No. 5, September-October, 1990, pp. 16-22

Feller, I. 1987. "Technology transfer, public policy and the cooperative extension service-OMB imbroglio." Journal of Policy Analysis and Management, 6: 307-327.

Feller, I. and D. Roessner. 1995. "What Does Industry Expect from University Partnerships; Congress Wants to See Bottom-Line Results from Industry/Government Programs, But That is Not What the Participating Companies Are Seeking." Issues in Science and Technology, 12(1):80.

Feller, I. and Menzel, D.C., 1977. "Diffusion milieus as a focus of research on innovation in the public sector." Policy Sciences. 8: 49-68.

Feller, I., P. Madden, L. Kaltreider, D. Moore and L. Sims. 1987. "The New Agricultural Research and Technology Transfer Policy Agenda." Research Policy, 16(6): 315.

Feller, Irwin, 1988, "Evaluating State Advanced Technology Programs," Evaluation Review, 12, 232-252.

Felsenstein, D. 1994. "Science Parks" (Review Article). Economic Geography, 70(January): 72-6.

Fenton, N., Pfleeger, S. L., and Glass, R. L. (1994, July/August). Science and substance: A challenge to software engineers. IEEE Software, 11(4), 86-95.

Fichman, R. G., and Kemerer, C. F. (1993, Winter). Adoption of software engineering process innovations: The case of object orientation. Sloan Management Review, 34(2), 7-22.

Fichman, R. G., and Kemerer, C. F. (1997, October). The assimilation of software process innovations: An organizational learning perspective. Management Science, 43(10), 1345-1363.

Fichman, R. G., and Kemerer, C. F. (1999, September). The illusory diffusion of innovation: An examination of assimilation gaps. Information Systems Research, 10(3), 255-275.

Finnegan, M.B., "R&D for Developing Countries: The Code of Conduct Issue," Vol. 22, No. 3, May 1979, pp. 39-41

Fischer, W. 1976. "Empirical approaches to understanding technology transfer." R&D Management. 6.

Fitzgerald, B. (1996, January). Formalized systems development methodologies: A critical perspective. Information Systems Journal, 6(1), 3-23.

Florida, R. 1995. "Technology Policy For A Global Economy." Issues in Science and Technology, 11(3): 49-56.

Florida, R. and M. Kenney 1994. "The Globalization Of Japanese R&D--The Economic Geography Of Japanese R&D Investment In The United States." Economic Geography, 70(0ctober): 344-69.

Foden, H., P. McNamara, and R. Koepke 1988. "Boosting industry competitiveness: Local-level technology transfer." Industrial Development. March/April.

Forje, J. W. 1995. "Development and technology policy in a changing society--challenges for the African political structures." Science & Public Policy, 22 (2): 121.

Foruria, C. and W. E. Souder 1995. "The Evolution And Transfer Of National Technologies - A Conceptual-Model With Comparative Case-Studies." Journal Of Scientific & Industrial Research, 54(4): 231-242.

Foster, R.N. 1971. "Organize for technology transfer." Harvard Business Review. Nov-Dec.

Fowler, P., & Levine, L. (1993, December). "Technology transition push: A case study of rate monotonic analysis (Part 1)." (CMU/SEI-93-TR-29). Software Engineering Institute, Pittsburgh, PA.

Fowler, P., & Levine, L. (1995, April [Note that the date from the edition ID is 1993]). "Technology transition pull: A case study of rate monotonic analysis (Part 2)." (CMU/SEI-93-TR-030). Software Engineering Institute, Pittsburgh, PA.

Fowler, P., & Rifkin, S. (1990, September). "Software engineering process group guide." (CMU/SEI-90-TR-24). Software Engineering Institute, Pittsburgh, PA.

Fredrikson, E.B. and Lawson, E.W., "The Role of Technology Transfer in Product Development and Marketing," Vol. 13, No. 4, July 1970, pp. 265-272

Freeman, C. and J. Hagedoorn 1992. "Globalization of Technology." Monitor-Fast Paper. (Brussels: Commission of the European Communities).

Freeman, C. and J. Hagedoorn 1994. "Catching Up Or Falling Behind - Patterns In International Interfirm Technology Partnering." World Development, 22(5): 771-780.

Frosch, R.A., "R&D Choices and Technology Transfer," Vol. 27, No. 3, May-June, 1984, pp. 11-14

Fryda, L. 1989. "Illinois plan for technology transfer at Illinois State University." Technology Transfer. Summer/Fall.

Fusfeld, H. 1986. The Technical Enterprise. (Cambridge, MA: Ballinger).

G

Gallon, M. 1980. "The State of Technical Innovation - A Case Study of the Electrical Vehicle in France." Research Policy, 9: 358-376.

Gander, J. P. 1986. "The Economics of University-Industry Research Linkages." Technological Forecasting and Social Change, 29(1): 33-51.

Gander, J. P. 1987. "University/Industry Research Linkages and Knowledge Transfers: A General Equilibrium Approach." Technological Forecasting and Social Change, 31(2): 117-130.

Gartner, J. and Naiman, C. 1976. "Overcoming the barriers to technology transfer." Research Management. March.

Gartner, J. and Naiman, C. 1978. "Making technology transfer happen." Research Management. May.

Gartner, Joseph and Naiman, C.S., "Making Technology Transfer Happen," Vol. 21, No. 3, May, 1978, pp. 34-38

Gartner, Joseph and Naiman, C.S., "Overcoming the Barriers to Technology Transfer," Vol. 19, No. 2, March, 1976, pp. 22-28

Garud, R., & Karnøe, P. (2001). Path creation as a process of mindful deviation. In "Path dependence and creation" (R. Garud, and P. Karnøe, Eds.), pp. 1-38. Lawrence Erlbaum Associates, Mahwah, NJ.

Gates, W. 1988. "Federally Supported Commercial Technology Development: Solar Thermal Technologies 1970-1982." Research Policy, 17(1): 27.

Gaw, J. L. (1999). "'A time to heal': The diffusion of Listerism in Victorian Britain." American Philosophical Society, Philadelphia, PA.

Gee, S. 1981. Technology Transfer; Innovation and Industrial Competitiveness. (New York: John Wiley & Sons).

Gee, Sherman, "The Role of Technology Transfer in Innovation," Vol. 17, No. 6, November, 1974, pp. 31-36

Geffen, C A. 1995. "Radical innovation in environmental technologies - the influence of federal policy." Science & Public Policy, 22 (5): 313.

Geisler, E. 1993. "Technology Transfer: Toward Mapping the Field, a Review, and Research Directions. Journal of Technology Transfer, 18(3&4): 88-93.

Geisler, E. 1997. "Intersector technology cooperation: Hard myths, soft facts." Technovation, 17(6): 309-320.

Geisler, E. and S. K. Kassicieh 1997. "Information technologies and technology commercialization - The research agenda." IEEE Transactions on Engineering Management, 44(4): 339-346.

Gelder, H. van. 1990. "ELAIN - Innovative Transfer of a Federal-Industry Network." Journal of Technology Transfer. 15 (1 & 2): 61.

Georgantzas, N. C. and C. N. Nadu. 1990. "Cognitive Processes in Technology Management and Transfer." Technological Forecasting and Social Change. 38(1): 81-96

Georghiou, L. G. and J. S. Metcalfe 1993. "Evaluation Of The Impact Of European Community Research Programs Upon Industrial Competitiveness." R&D Management, 23(2): 161-169.

Geroski, P. A. (2000). Models of technology diffusion. Research Policy, 29, 603-625.

Gerwin, D., V. Kumar, and S. Pal. 1992. "Transfer of Advanced Manufacturing Technology - From Canadian Universities to Industry." Journal of Technology Transfer, 17(2 & 3): 57.

Gibbons, J. H. and C. E. Woteki 1994. "Science In The National Interest." Issues in Science and Technology, 11(1): 19-21.

Gibbons, J.H. and H.L. Gwin 1989. "Lessons learned in twenty years of energy policy." Energy Systems and Policy, 13(1).

Giberson, W.E. 1969. "Management of technology transfer in an advanced project: The case of the surveyor." IEEE Transactions on Engineering Management. EM-16 (3): 125-129.

Gilbert, M. and M. Cordeyhayes 1996. "Understanding The Process Of Knowledge Transfer To Achieve Successful Technological Innovation." Technovation, 16(6): 301-312.

Gillespie,G. 1988. "Federal laboratories: Economic development and intellectual property constraints." Technology Transfer. 20-26.

Gillette, W. 1977. "How Regulations Encourage and Discourage Innovations." Research Management, (March).

Gladstone, N.J. 1986. "How not to promote technology transfer." Technology Review. 89.

Glaser, E. 1983. Putting knowledge to use: facilitating the diffusion of knowledge and implementation of planned change. (San Francisco, CA: Jossey-Bass).

Glass A. J. and K. Saggi 1998. "International technology transfer and the technology gap." Journal of Development Economics, 55(2): 369-398.

Glassman, A M. 1995. "Rethinking Organization Stability as a Determinant for Innovation Adoption and Diffusion." NIDA Research Monograph, 155: 132.

Glaziev, S. Yu., & Kaniosvki, Y. M. (1991). Diffusion of innovations under conditions of uncertainty: A stochastic approach. In "Diffusion of technologies and social behavior" (N. Naki_enovi_, and A. Grübler, Eds.), pp. 231-246. Springer-Verlag, Berlin.

Godkin, L. 1988. "Problems and practicalities of technology transfer: A survey of the literature." International Journal of Technology Management, 3(5).

Golden, W. T. and J. K. Stine 1994. "Worldwide Science And Technology Advice To The Highest Levels Of Governments." Isis, 85(1): 175-177.

Goldfarb, B. and Henrekson, M. “Bottom-up versus top-down policies towards the commercialization of university intellectual property.” Research Policy 32 (2003) 638-658.

Gomory, R.E., "Moving IBM's Technology from Research to Development," Research-Technology Management. Vol. 32, No. 6, November-December, 1989, pp. 27-32

Gover, J. "Corporate-Management Of Research-And-Development--Lessons For The United-States-Government." Research-technology Management, 38(2): 27-36.

Grady, R. B. , and Van Slack, T. (1994, July). Key lessons in achieving widespread inspection use. IEEE Software, 11, 46-57.

Granstrand, O. (1991). Temporal diffusion and population dynamics: A systems model. In "Diffusion of technologies and social behavior" (N. Naki_enovi_, and A. Grübler, Eds.), pp. 247-263. Springer-Verlag, Berlin.

Grant, E. B. and M. J. 1997. "Tacit knowledge, the life cycle and international manufacturing transfer." Technology Analysis & Strategic Management, 9(2): 149-161.

Grant, E. B. and M. J. Gregory 1997. "Adapting manufacturing processes for international transfer." International Journal Of Operations & Production Management, 17(9-10): 994.

Gray, D., et al 1986. "NSF's industry-university cooperative R&D centers program and the innovation process: Evaluation-based lessons." in Technological Innovation D. Gray (ed.) (Amsterdam: Elsevier).

Green S. G., M. A. Welsh and G. E. Denier 1996. "Transferring technology into R&D: A comparison of acquired and in-house product development projects." Journal of Engineering and Technological Management, 13(2): 125-144.

Green, J., J. Brupbacher and D. Goldheim. 1991. "Strategic Partnering Aids Technology Transfer." Research Technology Management, 34(4): 26.

Greene, C. Scott. 1984. "Public policy, technology, and ethics: Marketing decisions for NASA's space shuttle." Journal of Marketing. 48: 56-67.

Griliches, Zvi, 1990, “Patent Statistics as Economic Indicators: A Survey,” Journal of Economic Literature, 28, 1661-1707.

Grliches, Zvi, 1979, “Issues in Assessing the Contribution of Research and Development to Productivity Growth,” Bell Journal of Economics, 92-116.

Grosse, R. 1996. "International technology transfer in services." Journal of International Business Studies, 27(4): 781-800.

Gruber, W.A. and Marquis, D.G. 1969. Factors in the Transfer of Technology. (Cambridge, MA: MIT Press.)

Grubler, A. 1996. "Time For A Change—On The Patterns Of Diffusion Of Innovation." Daedalus, 125(3): 19-42.

Grupp, H. 1994. "Linking International Technology Transfer With Strategy and Management: A Literature Commentary." Research Policy, 23(2): 175-217.

Gudmestad, T. and Gudmestad, O.T., "Protecting Intellectual Property During Divestitures and Acquisitions," Vol. 41, No. 5, September-October, 1998, pp. 36

H

Hagedoorn, J. 1989. The Dynamic Analysis of Innovation and Diffusion. (London: Frances Pinter).

Hagedoorn, J. 1990. "Organizational modes of inter-firm cooperation and technology transfer." Technovation. 10(1).

Hagedoorn, J. 1995. "Strategic Technology Partnering During the 1980s: Trends Networks and Corporate Patterns In Non-Core Technologies." Research Policy, 24(2): 207-233.

Hahm S. D., L. C. Pleon and R. Florida 1994. "The Politics Of International Technology-Transfer--Lessons From The Korean Experience." Policy Studies Journal, 22(2): 311-321.

Hall, B. H., A. B. Jaffe, and M. Tratjenberg, 2001. “The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools.” National Bureau of Economic Research Working Paper No. 8498.

Hall, B.H., A. Jaffe, and M. Trajtenberg, 2000, “Market Value and Patent Citations: A First Look,” National Bureau of Economic Research Working Paper No. 7741.

Ham R. M. and D.C. Mowery 1997. "Technology transfer and collaboration between industry and national laboratories." International Journal Of Industrial Engineering-Applications And Practice, 4(4): 244-253.

Ham, R. M. and D. C. Mowery. 1995. "Improving Industry-Government Cooperative R&D: You Won t Find A Treasure Chest of Market-Ready Technologies at the National Labs, But You Can Find Opportunities for Productive Collaboration." Issues in Science and Technology, 11(4): 67.

Hameri, A. P. 1996. "Technology-Transfer Between Basic Research And Industry." Technovation, 16(2): 51-57.

Hannay, N.B. and Steele, L.W., "Technology and Trade: A Study of U.S. Competitiveness in Seven Industries," Vol. 29, No. 1, January-February, 1986, pp. 14-22

Hardgrave, B. C. (1997, April). Adopting object-oriented technology: Evolution or revolution? Journal of Systems & Software, 37(1), 19-25.

Harmon, B., A. Ardishvili, R. Cardozo, et al. 1997. "Mapping the university technology transfer process." Journal of Business Venturing, 12(6): 423-434.

Harris, M. (1996, March). Organizational politics, strategic change and the evaluation of CAD. Journal of Information Technology, 11(1), 51-8.

Hartmann, G.C. and Lakatos, A.I., "Assessing Technology Risk," Vol. 41, No. 2, March-April, 1998, pp. 32

Harvey, M. 1984. "Application of Technology Life Cycles to Technology Transfers." The Journal of Business Strategy, Fall: 51-58.

Hauschildt, J. 1992. "External Acquisition Of Knowledge For Innovations--A Research Agenda." R&D Management, 22(2): 105-110.

Hawkins, W.M. 1969. "Technology transfer programs at Lockheed." IEEE Transactions on Engineering Management. EM-16(3): 121-124.

Hayden, E.W., 'Transferring Technology to the Soviet Bloc: U.S. Corporate Experience," Vol. 19, No. 5, September, 1976, pp. 17-23

Hayes, K. C. 1990. "The Role of Libraries in Technology Transfer for Agriculture." Science & Technology Libraries, 11(2): 77.

Headrick, D. R. 1998. "Technology and European overseas enterprise: Diffusion, adaption, and adoption." Technology and Culture, 39(2): 352-354.

Hecker, S. S. 1994. "Retargeting The Weapons Laboratories." Issues in Science and Technology, 10(3): 44-51.

Hedley. R. A. 1998. "Technological diffusion or cultural imperialism? Measuring the information revolution." International Journal Of Comparative Sociology, 39(2): 198-212.

Heilmeier, G. H. 1993. "Reflections On Innovation, Invention, And Industrial Policy." Chemtech. 23(May): 7-9.

Heller, P. 1985. Technology Transfer and Human Values: Concepts, Applications, Cases. (Lanham, MD: University Press of America).

Hendry, J. and A. Norberg 1992. "Innovating For Failure--Government Policy And The Early British Computing Industry." Isis, 83(4): 688-690.

Herman, J. 1983. "Redefining the federal government's role in technology transfer." Research Management. 21-24.

Herman, R. 1994. "Co-ordinating research and technological development in Europe--lessons from the German system." Science & Public Policy, 21(6): 358.

Herrman, J.F., "Redefining the Federal Government's Role in Technology Transfer," Vol. 26, No. 1, January-February, 1983, pp. 21-24

Hewitt, W. E. 1996. "International municipal exchange as a catalyst for South-North technology and information transfer: A case study from the Americas." Canadian Journal Of Development Studies, 17(2): 293-311.

Hicks, D. 1993. "University-Industry Research Links In Japan." Policy Sciences, 26(4): 361-395.

Hinman, G., L. Icerman and L. Seig. 1986. "Commercializing New Technology-Based Start-Up Industries." Research Management, 29(1): 31-36.

Hiraoka, L. S. 1995. "Japan Coordinated Technology-Transfer And Direct Investments In Asia." International Journal of Technology Management, 10(7-8): 714-731.

Hirschheim, R., and Newman, M. (1988). Information systems and user resistance: Theory and practice. Computer Journal, 31(5), 398-408.

Hisrich, R., & Smilor, R. 1988. "The university and business incubation: Technology transfer through entrepreneurial development." Technology Transfer. 14-19.

Hoetker, G. 1997. "International technology transfer and the World Wide Web." Database, 20(3): 20.

Hofmann, J. 1995. "Implicit Theories In Policy Discourse – An Inquiry Into The Interpretations Of Reality In German Technology Policy." Policy Sciences, 28(2): 127-148.

Holley, J & R A Wilkens. 1994. "Flexible Manufacturing Networks - Strategies for Economic Renewal." Journal of Technology Transfer, 19(2): 11.

Holstius, K. 1995. "Cultural Adjustment In International Technology-Transfer." International Journal Technology Management, 10(7-8): 676-686.

Horn, P.M., "Information Technology Will Change Everything," Vol. 42, No. 1, January-February, 1999, pp. 42

Howell, Larry J., "Globalization Within the Auto Industry." Vol. 45, No. 4, July-August 2002 pp. 43-49

Howells, J. 1990. "The Globalisation of Research and Development: A New Era of Change?" Science and Public Policy, 17: 273-285.

Howells, J. 1996. "Tacit knowledge, innovation and technology transfer." Technology Analysis & Strategic Management, 8(2): 91-106.

Howells, J. 1997. "Rethinking the market-technology relationship for innovation." Research Policy, 25(8): 1209-1219.

Huff, S. L., and Munro, M. C. (1985). Information technology assessment and adoption: A field study. MIS Quarterly, 327-339.

Huffamn, D. 1985. "Software support systems for use in technology transfer activities." Journal of Technology Transfer. 9(2): 29.

I

Iivari, J. (1995, August). Factors affecting perceptions of CASE effectiveness. European Journal of Information Systems, 4(3), 143-158.

Iivari, J. (1996, October). Why are CASE tools not used? Communications of the ACM, 39(10), 94-103.

“Innovation’s Golden Goose,” The Economist Technical Quarterly, December 12, 2002.

Ives, B., and Olson, M. H. (1984, May). User involvement and MIS success: A review of research. Management Science, 30(5), 586-603.

J

Jaakkola, H. (1996). Comparison and analysis of diffusion models. In "Diffusion and adoption of information technology: Proceedings of the first IFIP WG 8.6 working conference on the diffusion and adoption of information technology" (Kautz, Karlheinz and Pries-Heje, Jan, Eds.), Oslo, Norway, pp. 65-82. Chapman & Hall, London.

Jaffe A. B., M. S. Fogarty and B. A. Banks 1998. "Evidence from patents and patent citations on the impact of NASA and other federal labs on commercial innovation." Journal of Industrial Economics, 46(2): 183-205.

Jaffe, A. B. 1986. "Technological Opportunities and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value." The American Economic Review, 76(5).

Jaffee, Adam B, 1986, "Technological Opportunity and Spillovers of R&D: Evidence from firms' Patents, Profits, and Market Value," American Economic Review, 76:5, 984-1001.

Janes, M. C. 1996. "A Review Of The Development Of Technology Assessment." International Journal of Technology Management, 11(5-6): 507-522.

Janis, Timothy F, 1997, "Metrics Definition Matrix," in Sally A. Rood, ed, Proceedings: Technology Transfer Metrics Summit, Technology Transfer Society, 289-295.

Jensen, Richard and Marie Thursby, 2001, "Proofs and Prototypes for Sale: The Licensing of University Inventions," American Economic Review, 91(1) March, pp 240-259.

Jermier, J. M., Knight, D., & Nord, W. R. (1994). Resistance and power in organizations: Agency, subjectivity and the labour process. In "Resistance and power in organizations" (J. M. Jermier, D. Knight, and W. R. Nord, Eds.). Routledge, London.

Jervis, P. 1975. "Innovation and technology transfer -- the roles and characteristics of individuals." IEEE Transactions on Engineering Management. EM-22 (I): 19-26.

Jolly, J.A. and J.W. Creighton 1977. "The technology transfer process: Concepts, framework, and methodology." Journal of Technology Transfer. 1(2).

Jones, R., Ed. 1988. "In this high technology success story, everybody benefits." Research & Development. 74-78.

Joshi, B. 1977. "International transfer of technology system." IEEE Transactions on Engineering Management. EM-24 (3): 86-93.

Jurison, J. (2000, October-December). Perceived value and technology adoption across four end user groups. Journal of End User Computing, 12(4), 21-28.

K

Kabiraj T. and S. Marjit 1993. "International Technology-Transfer Under Potential Threat Of Entry--A Cournot-Nash Framework." Journal of Development Economics, 42(1): 75-88.

Kaimowitz, D. 1993. "The Role Of Nongovernmental Organizations In Agricultural-Research And Technology-Transfer In Latin-America." World Development, 21(7): 1139-1150.

Kanter, R. M. (1983). "The change masters: Innovation & entrepreneurship in the American corporation." Simon & Schuster, New York, NY.

Kanter, R. M. (1987, May). Managing traumatic change: Avoiding the 'unlucky 13'. Management Review, 76(5), 23-24.

Kanter, R. M. (1988, January). Change masters: Playing a new game. Executive Excellence, 5(1), 8-9.

Kanter, R. M. (1988, March). Change masters vs. change stiflers. Executive Excellence, 5(3), 12-13.

Kanter, R. M. (1989). "When giants learn to dance." Simon & Schuster, New York, NY.

Kanter, R. M. (1989, December). "Improving the acceptance and use of new technology: Organizational and inter-organizational challenges." (Working Paper 90-043). Division of Research, Harvard Business School.

Kanter, R. M. (1989, Summer). Swimming in newstreams: Mastering innovation dilemmas. California Management Review, 31(4), 45-69.

Kanter, R. M. (1990, November/December). Thinking across boundaries. Harvard Business Review, 68(6), 9.

Kanter, R. M. (1991, January/February). Championing change: An interview with Bell Atlantic's CEO Raymond Smith. Harvard Business Review, 69(1), 118-130.

Kanter, R. M. (1991, July/August). Change: Where to begin. Harvard Business Review, 69(4), 8.

Kanter, R. M. (1991, May/June). Transcending business boundaries: 12,000 world managers view change. Harvard Business Review, 69(3), 151-164.

Kanter, R. M. (1992, January/February). Discipline! Harvard Business Review, 70(1), 7.

Kanter, R. M. (1992, Mar/April). Six certainties for CEOs. Harvard Business Review, 70(2), 7.

Kanter, R. M. (1992, May/June). Ourselves versus ourselves. Harvard Business Review, 70(3), 8.

Kanter, R. M. (1993, April). Mastering change. Executive Excellence, 10(4), 11.

Kanter, R. M. (1996, December 2). Can giants dance in cyberspace? Forbes (ASAP), 247-248.

Kanter, R. M. (1997). "Frontiers of management." Harvard Business School, Boston, MA.

Kanter, R. M. (1999, May/June). From spare change to real change. Harvard Business Review, 77(3), 122-132.

Kanter, R. M. (2000, May/June). The enduring skills of change leaders. Ivey Business Journal, 64(5), 31-36.

Kanter, R. M., and Corn, R. I. (1994). Do cultural differences make a business difference? Contextual factors affecting cross-cultural relationship success. Journal of Management Development, 13(2), 5-23.

Kanter, R. M., and Fonvielle, W. H. (1987, January). When to persist and when to give up. Management Review, 76(1), 14-15.

Kanter, R. M., and Parkes, C. (1991, June). In search of a single culture. Business (London), 58-66.

Kanter, R. M., and Richardson, L. (1991, May). Engines of progress: Designing and running entrepreneurial vehicles in established companies - the Enter-Prize Program at Ohio Bell, 1985-1990. Journal of Business Venturing, 6(3), 209-229.

Kanter, R. M., and Stein, B. A. (1992, November). New models, but where's the process? -- Transforming Organizations edited by Thomas A. Kochan and Michael Useem. Contemporary Sociology, 21(6), 758.

Kanter, R. M., North, J., Bernstein, A. P., and Williamson, A. (1990, November). Engines of progress: Designing and running entrepreneurial vehicles in established companies. Journal of Business Venturing, 5(6), 415-27.

Kanter, R. M., North, J., Richardson, L., Ingols, C., and Zolner, J. (1991, March). Engines of progress: designing and running entrepreneurial vehicles in established companies: Raytheon's new product center, 1969-1989. Journal of Business Venturing, 6(2), 145-163.

Kanter, R. M., Richardson, L., North, J., and Morgan, E. (1991, January). Engines of progress: Designing and running entrepreneurial vehicles in established companies; the new venture process at Eastman Kodak, 1983-1989. Journal of Business Venturing, 6(1), 63-82.

Kanter, R. M., Stein, B. A., & Jick, T. D. (compiled by). (1992). "The challenge of organizational change: How companies experience it and leaders guide it." Free Press, New York, NY.

Kanter, Rosabeth Moss, John Kao, and Fred Wiersema, eds. Innovation: Breakthrough Thinking at 3M, DuPont, GE, Pfizer and Rubbermaid, Harper Business, 1997, pp. 84-85

Kaplan, A. (1964). "The conduct of inquiry: Methodology for behavioral science." Chandler Pub. Co., San Francisco.

Kaplan, E. 1972. Japan: The Government-Business Relationship. (Washington, DC: USGPO).

Karahanna, E., Straub, D. W., and Chervany, N. L. (1999, June). Information technology adoption across time: A cross-sectional comparison of pre-adoption and post-adoption beliefs. MIS Quarterly, 23(2), 183-213.

Karani, P. and J. B. Ojwang 1996. "Intellectual property in international relations--Technology transfer." Science Communication, 17(3): 326-337.

Kash, D. E. and R. W. Rycroft 1995. "United-States Federal-Government Research-And-Development And Commercialization—You Can't Get There From Here." R&D Management, 25(1): 71-89.

Kassicieh and Radosevich, From Lab to Market, Plenum Press, New York, 1994.

Kassicieh, S. K. & H. R. Radosevich. 1991. "A Model for Technology-Transfer Group-Decision Support Systems and Electronic Meetings." Journal of Technology Transfer, 16(3): 43.

Kassicieh, S. K., H. R. Radosevich and J. Senker 1996. "From Lab To Market--Commercialization Of Public-Sector Technology" Research Policy, 25(3): 482-484.

Katrak, H. 1997. "The private use of publicly funded industrial technologies in developing countries: Empirical tests for an industrial research institute in India." World Development, 25(9): 1541-1550.

Katz, R., E. S. Rebentisch and T. J. Alien 1996. "A Study Of Technology-Transfer In A Multinational Cooperative Joint

Kautz, K., & Pries-Heje, J. (1996). "Diffusion and adoption of information technology (Proceedings of the first IFIP WG 8.6 working conference on the diffusion and adoption of information technology)" , Oslo, Norway, Chapman & Hall, London.

Kimzy, Charles H., "Technology Outsourcing in the U.S and Japan." Vol. 45, No. 4, July - August 2002 pp. 36-42

Kniel, C.R., “Laboratory Technology Research (LTR) Industry Partner Survey,” E.O. Lawrence Berkeley National Laboratory, October 1998 (LBID-2253). (http://www.lbl.gov/tt/collaboration/partnerships/LTR_Survey/index.html)

Kottenstette, J.P. and Rusnak, J.J., 'Transfer and Diffusion: Two Ways to Transmit Technology," Vol. 16, No. 4, July, 1973, pp. 24-27

Krantz, J. (1999, March). Comment on "Challenging 'resistance to change'". Journal of Applied Behavioral Science, 35(1), 42-44.

Kuilboer, J. P., and Ashrafi, N. (1999). Software process improvement deployment: An empirical perspective. Journal of Information Technology Management, 10(3-4), 35-47.

Kunnathur, A. S., Ahmed, M. U., and Charles, R. J. S. (1996, January). Expert systems adoption: An analytical study of managerial issues and concerns. Information Management, 30(1), 15-25.

Kwon, T. H., & Zmud, R. W. (1987). Unifying the fragmented models of information systems implementation. In "Critical issues in information systems research" (R. J. Boland, Jr., and R. A. Hirschheim, Eds.), pp. 227-251. John Wiley, Chichester, England.

L

Laamanen T. and E. Autio 1996. "Dominant dynamic complementarities and technology-motivated acquisitions of new, technology-based firms." International Journal of Technology Management, 12(7-8): 769-786.

Lai, V. S. and J. L. Guynes, 1997. “An assessment of the influence of organizational characteristics on information technology adoption decision: a discriminative approach,” IEEE Transactions on Engineering Management, 44(2), pp 146-157.

Lam, A. 1997. "Embedded firms, embedded knowledge: Problems of collaboration and knowledge transfer in global cooperative ventures." Organization Studies, 18(6): 973-996.

Lambe C. J. and R. E. Spekman 1997. "Alliances, external technology acquisition, and discontinuous technological change." Journal Of Product Innovation Management, 14(2): 102-116.

Lambright, W. H. 1979. Technology Transfer to Cities. (Boulder, CO: Westview Press).

Lambright, W.H. and Teich, A.H. 1976. "Technology transfer as a problem in interorganizational relationships." Administration and Society 8(1).

Lange, R., McDade, S., and Oliva, T. A. (2001, March). Technological choice and network externalities: A catastrophe model analysis of firm software adoption for competing operating systems. Structural Change & Economic Dynamics, 12 (1), 29-57.

Large D. W. and D. W. Barclay 1992. "Technology-Transfer To The Private-Sector--A Field-Study Of Manufacturer Buying Behavior." Journal Of Product Innovation Management, 9(1): 26-43.

Large, D. W. & K. Belinko. 1995. "Building Successful Technology Transfer Teams - A Theory of Cascading Commitment." Journal of Technology Transfer, 20(1): 67.

Larsen, J. and R. Widgard 1987. "Industry-university technology transfer in microelectronics.' Policy Studies Review, 6: 584-595.

Larsen, T. (2001). The phenomenon of diffusion: Red herrings and future promises. In "Diffusing software product and process innovations (Proceedings of the IFIP TC8 WG8.6

fourth working conference on diffusing software product and process innovations)" (Ardis, Mark A. and Marcolin, Barbara L., Eds), Banff, Canada, pp. 35-50. Kluwer Academic Press, Boston.

Larsen, T. J., & McGuire, E. (Eds.). (1998). "Information systems innovation and diffusion: issues and directions." Idea, Hershey, PA.

Lassila, K. S., and Brancheau, J. C. (1999, Fall). Adoption and utilization of commercial software packages: Exploring utilization equilibria, transitions, triggers, and tracks. Journal of Management Information Systems, 16(2), 63-90.

Lauer, R. D. 1995. "Scientists and the State-Domestic Structure and International Context." Journal of Technology Transfer, 20(2): 55.

Lawrence, P. , and Lorsch, J. (1967). "Organization and environment: Managing differentiation and integration." Irwin, Homewood, IL.

Lederman, L. L. 1994. "A Comparative Analysis Of Civilian Technology Strategies Among Some Nations - France, The Federal Republic Of Germany, Japan, The United Kingdom And The United States" (Part Of A Symposium On Technology Transfer And Public Policy). Policy Studies Journal, 22(2): 279-95.

Lee T. J., M. H. Yang and Z. T. Bae 1998. "The improvement of spin-offs from national nuclear R&D activities in Korea" Nuclear Energy-Journal Of The British Nuclear Energy Society, 37(5): 337-341.

Lee, C. 1988. "The Role Of The Government And R&D Infrastructure For Technology Development." Technological Forecasting and Social Change, 33: 33-54.

Lee, C., Z. T. Bae and J. J. Lee 1994. "Strategies For Linking Vertical Cooperative Research-And-Development To Commercialization In Korea." Journal Of Product Innovation Management, 11(4): 325-335.

Lee, Y. and R. Gaertner 1994. "Technology-Transfer From University To Industry - A Large-Scale Experiment With Technology Development And Commercialization." Policy Studies Journal, 22(2): 384-399.

Lee, Y. S. 1996."'Technology transfer' and the research university: A search for the boundaries of university-industry collaboration." Research Policy, 25(6): 843-863.

Lee, Y. S. 1998. "University-industry collaboration on technology transfer: Views from the ivory tower." Policy Studies Journal, 26(1): 69-84.

Lee, Y. S. ed. 1994. "Technology Transfer And Public Policy-- Preparing For The Twenty-First Century." (Symposium) Policy Studies Journal, 22(2): 259-399.

Lehman, E.J. 1986. "Opportunities for states to link businesses with federal technologies and resources." Technology Transfer Society International Symposium Proceedings 1986.

Leonard-Barton, D. (1988, October). Implementation as mutual adaptation of technology and organization. Research Policy, 17(5), 251-267.

Levin, M. 1993. "Technology-Transfer As A Learning And Developmental Process - An Analysis Of Norwegian Programs On Technology-Transfer." Technovation, 13(8): 497-518.

Levine, L. 1994. "Diffusion, transfer and implementation of information technology (Proceedings of the IFIP TC8 Working Conference)" , Pittsburgh, PA, North-Holland, Amsterdam.

Levine, L. (1997). An ecology of resistance. In "Facilitating technology transfer through partnership: Learning from practice and research (Proceedings of the IFIP TC8 WG8.6 International Working Conference on Diffusion, Adoption and Implementation of Information Technology)" (McMaster, Tom, Mumford, E., Swanson, E. B., Warboys, B., and Wastell, David, Eds.), Ambleside, Cumbria, UK, pp. 163-174. Chapman & Hall, London.

Libicki, M., et al. (2000). "Scaffolding the New Web: Standards and Standards Policy for the Digital Economy." RAND, Santa Monica, California, 2000.

Lichtenberg, F. R. and B. V. de la Potterie 1998. "International R&D spillovers: A comment." European Economic Review, 42(8): 1483-1491.

Lien, A.P., "Acquiring and Selling Technology: The Role of the Middleman," Vol. 22, No. 3, May, 1979, pp. 29-31

Link, A and G Tassey. forthcoming. "Standards and the Diffusion of Advanced Technologies." Evaluation and Program Planning.

Link, A. 1982. "A Disaggregated Analysis of Industrial R&D: Product versus Process Innovation," in The Transfer and Utilization of Technical Knowledge. D. Sahal (ed.) (Lexington, MA: D.C. Heath).

Link, A. 1983. "Alternative Sources of Technology: An Analysis of Induced Innovations." Managerial and Decision Economics.

Link, A. and B. Zmud 1987. "External Sources of Technical Knowledge." Economic Letters, July.

Link, A.N. and J. Rees, 1990, "Firm Size, University Based Research and the Returns to R&D," Small Business Economics, 2, 25-32.

Linsteadt, G.F. and L. Doig III 1987. "Maintaining the high-tech edge: government-industry technology transfer and the federal laboratory system in California." Journal of Technology Transfer, 12(1).

Linstone, H. A. (1991). Multiple perspectives on technological diffusion: Insights and lessons. In "Diffusion of technologies and social behavior" (N. Naki_enovi_, and A. Grübler, Eds.), pp. 53-92. Springer-Verlag, Berlin.

Liyanage, S. 1995. "Breeding Innovation Clusters Through Collaborative Research Networks." Technovation, 15(9): 553-567.

Long, W. J. 1992. "Proliferating Problems--United-States Management Of Strategic Technology After The Cold-War." Technological Society, 14(4): 363-376.

Lopata, C. L. (June 1993). The cooperative implementation of information technology: a process of mutual adaptation. Unpublished doctoral dissertation, Drexel University, Philadelphia, PA.

Lopes, S. 1994. "Technology Transfer in the Americas." Journal of Technology Transfer, 19(2): 25.

Lopez Eguilaz, M. J. and S. Perez 1997. "The measurement of technology transfer: Situation in Spain." International Journal of Technology Management, 13(2): 153-164.

Lucas, H. C., Jr., Ginsberg, M. J., and Schultz, R. L. (1990). "Information systems implementation: Testing a structural model." Ablex, Norwood, NJ.

Lynn, L. H., N. M. Reddy and J. D. Aram 1996. "Linking Technology And Institutions--The Innovation Community Framework." Research Policy, 25(1): 91-106.

Lyytinen, K. (1991). Penetration of information technology in organizations: A comparative study using stage models and transaction costs. Scandinavian Journal of Information Systems, 3.

Lyytinen, K. , & Damsgaard, J. (2001). What's wrong with the diffusion of innovation theory? A case of complex and networked technology. In "Diffusing software product and process innovations (Proceedings of the IFIP TC8 WG8.6 fourth working conference on diffusing software product and process innovations)" (Ardis, Mark A. and Marcolin, Barbara L., Eds), Banff, Canada, pp. 173-189. Kluwer Academic Press, Boston.

M

Maansaari, J., and Iivari, J. (1999, July). The evolution of CASE usage in Finland between 1993 and 1996. Information & Management, 36(1), 37-53.

Machiup, F. 1962. The Production and Distribution of Knowledge in the United States. (Princeton: Princeton University Press).

Madu, C. N. 1990. "Cognitive Mapping in Technology Transfer." Journal of Technology Transfer, 15(3): 33.

Madu, C., & Jacob, R. 1989. "Strategic planning in technology transfer: A dialectical approach." Technological Forecasting and Social Change, 35: 327-338.

Mahajan, V and E. Muller. 1996. "Timing, Diffusion, and Substitution of Successive Generations of Technological Innovations: The IBM Mainframe Case." Technological Forecasting and Social Change, 51(2): 109-133.

Mahajan, V., and Peterson, R. A. (1985). "Models for innovation diffusion." Sage, Beverly Hills, CA.

Mahajan, V., Muller, E., & Wind, Y. (Eds.). (2000). "New-product diffusion models." Kluwer Academic, Boston.

Mahajan, V., Muller, E., and Bass, F. M. (1990, January). New product diffusion models in marketing: A review and directions for research. Journal of Marketing, 54, 1-26.

Maier, F. H. (1998, Winter). New product diffusion models in innovation management -- a system dynamics perspective. System Dynamics Review, 14(4), 285-308.

Maital, S., A. Frenkel, H. Grupp, and K. Koschatzky. 1994. "Relation between scientific and technological excellence and export performance - theoretical model and empirical test for EC countries." Science & Public Policy, 21 (3): 138.

Major, J. 1988. "Some practical intellectual property aspects of technology transfer." International Journal of Technology Management, 3(1-2): 43-50.

Makino, S. and A. Delios 1996. "Local knowledge transfer and performance: Implications for alliance formation in Asia." Journal of International Business Studies, (5): 905-927.

Malecki, E. 1981. "Government Funded R&D: Some Regional Economic Implications." The Professional Geographer, 33(I):72-82.

Malecki, E. 1981. "Science Technology and Regional Economic Development: Review and Prospects." Research Policy, 10: 312-334.

Malerba, F., L. Orsenigo and P. Peretto 1997. "Persistence of innovative activities, sectoral patterns of innovation and international technological specialization." International Journal Of Industrial Organization, 15(6): 801-826.

Malik K., "How BICC Cables Transferred a New Process Technology From R&D to Manufacturing," Vol. 44, No. 4, July-August 2001. pp. 55

Manning, G.K. (ed.) 1974. Technology transfer: success and failures. (San Francisco, CA: San Francisco Press).

Mansfield, E. 1975. "International Technology Transfer: Forms, Resource Requirements, And Policies." American Economic Review, 65: 372-376.

Mansfield, E., A. Romeo, M. Schwartz, D. Teece, S. Wagner, and P. Branch 1982. Technology transfer, productivity, and economic policy. (New York: Norton Publishing.)

Mansfield, E., A. Romeo, M. Schwartz, D. Teece, S. Wagner, and P. Branch 1983. "New findings in technology transfer, productivity and development." Research Management, (March-April): 11-20.

Mansfield, E., Romeo, A., Schwartz, M., Teece, D., Wagner, S. and Brach, P., "New Findings in Technology Transfer Productivity and Economic Policy," Vol. 26, No. 2, March-April, 1983, pp. 11-20

Mansfield, Edwin, "Economic Impact of International Technology Transfer," Vol. 17, No. 1, January, 1974, pp. 7-11

Mansfield, Edwin, 1980. "Basic Research and Productivity Increase in Manufacturing," American Economic Review, 70, 863-73.

Marazita, C. F., 1991. "Technology Transfer in the United States: Industrial Research at Engineering Research Centers Versus the Technological Needs of US Industry." Technological Forecasting and Social Change, 39(4): 397-410.

Marcus, A. D., "Bose and Arrows," Wall Street Journal, July 20, 1999.

Markhan, S.K, "Moving Technology From Lab to Market"," Vol. 45, No. 6, November-December, 2002, pp 31-42

Markus, M. L. (1983, June). Power, politics, and MIS implementation. Communications of the ACM, 26(8), 430-444 .

Markus, M. L., and Robey, D. (1988, May). Information technology and organizational change: Causal structure in theory and research. Management Science, 34(5), 583-598.

Marshall, T. E., Byrd, T. A., Gardiner, L. R., and Rainer, R. K. Jr. (2000, July-September). Technology acceptance and performance: An investigation into requisite knowledge. Information Resources Management Journal, 13(3), 33-45.

Martinet, E., J. E. Sinton and B. M. Haddad, 1997. "International technology transfer for climate change mitigation and the cases of Russia and China." Annual Review Of Energy And The Environment, 22: 357-401.

Marvasti, A., 1998. "An assessment of the international technology transfer systems and the new Law of the Sea." Ocean and Coastal Management 39(3): 197-210.

Mathur, S. and A. P. Sinha 1997. "Transfer of computer technology in India--Case of B-CACHI." Economic and Political Weekly, 32(22): M70-M76.

Matkin, G. W. "Technology Transfer And Public Policy--Lessons From A Case Study" (Part Of A Symposium On Technology Transfer And Public Policy). Policy Studies Journal, 22(2): 371-383.

Matlack , C., 1987. "The administration and congress are eager to enlist university researchers to make the nation more competitive, but skeptics wonder of innovation can be programmed." National Journal. 1348-1353.

Mattila, 0., 1986. "Transferring technology across borders -- from the point of view of a neutral country." International Journal of Technology Management, 1(1-2): 13-21.

McFeeley, B. (1996, February). "IDEAL: A user's guide for software process improvement." (CMU/SEI-96-HB-001). Software Engineering Institute, Pittsburgh, PA.

Mclntyre, J. and D. Papp eds., 1986. Political Economy of International Technology Transfer.

McMaster, T., 2001. The illusion of diffusion in information systems research. In "Diffusing software product and process innovations (Proceedings of the IFIP TC8 WG8.6 fourth working conference on diffusing software product and process innovations)" (Ardis, Mark A. and Marcolin, Barbara L., Eds), Banff, Canada, pp. 67-86. Kluwer Academic Press, Boston.

McMaster, T., Mumford, E., Swanson, E. B., Warboys, B., & Wastell, D. (1997). "Facilitating technology transfer through partnership: Learning from practice and research (Proceedings of the IFIP TC8 WG8.6 international working conference on diffusion, adoption and implementation of information technology)" , Ambleside, Cumbria, UK, Chapman & Hall, London.

McMaster, T., Vidgen, R. T., & Wastell, D. G. (1997). Technology transfer: diffusion or translation? In "Facilitating technology transfer through partnership: Learning from practice and research (Proceedings of the IFIP TC8 WG8.6 international working conference on diffusion, adoption and implementation of information technology)" (McMaster, Tom, Mumford, Enid, Swanson, E. Burton, Warboys, Brian, and Wastell, David, Eds.), Ambleside, Cumbria, UK, pp. 64-75. Chapman & Hall, London.

Medcof J. W., 1997. "A taxonomy of internationally dispersed technology units and its application to management issues." R&D Management, 27(4): 301-318.

Melkers, Julia E. and Susan E. Cozzens, 1997, "A Review of Performance Measurement in State Science and Technology-Based Economic Development Programs," in Sally A. Rood, ed, Proceedings: Technology Transfer Metrics Summit, Technology Transfer Society, 109-117.

Mendelsohn, L. D., 1992. "Technology-Transfer Policy - Its Role As A Scientific And Technical-Information Policy And Its Impact On Technological Growth." Journal of the American Society for Information Science, 43(1): 80-88.

Merrifield, B., 1986. "R&D Limited Partnerships Are Starting to Bridge the Invention-Translation Gap." Research Management. 29(3): 9-13.

Merril, S.B. and John, C.T., "You Can Measure External Research Progress," Vol. 44, No. 3, May-June, 2001, pp. 14

Merron, K. (1993, Winter). Let's bury the term "resistance". Organization Development Journal, 11(4), 77-86.

Mervis, J., 1994. "Defense Conversion Comes To Campus." Science, 263 (March 25): 1676-8.

Metcalf, J. S., 1981. "Impulse and diffusion in the study of technological change." Futures, 13: 347-359.

Meyerson, D. , and Martin, J. (1987, November). Cultural change: An integration of three different views. Journal of Management Studies, 24(6), 623-647.

Mian, S. A. 1994. "United-States University-Sponsored Technology Incubators--An Overview Of Management, Policies And Performance." Technovation, 14(8): 515-528.

Miller, W. R., and Rollnick, S. (1991). "Motivational interviewing: Preparing people to change addictive behavior." Guilford Press, New York, NY.

Mogavero, L. N. and R. S. Shane. 1982. What Every Engineer Should Know About Technology Transfer and Innovation. (New York: Marcel Dekker Inc.).

Molas-Gallart, J. 1997. "Which way to go? Defence technology and the diversity of 'dual-use' technology transfer." Research Policy, 26(3): 367-385.

Molina, A. H. 1992. "Europe's IT strategy moves closer to the users - the Open Microprocessor Systems Initiative (OMI)." Science & Public Policy, 19 (3): 145.

Moodie, M. 1995. "Beyond Proliferation - The Challenge Of Technology Diffusion." Washington Quarterly, 18(2): 183-202.

Moon M. J. and S. Bretschneider 1997. "Can state government actions affect innovation and its diffusion?: An extended communication model and empirical test." Technological Forecasting and Social Change, 54 (1): 57-77.

Moore, G. A. (1991). "Crossing the chasm: marketing and selling technology products to mainstream customers." HarperBusiness, New York, NY.

Moore, G. A., 1991. Crossing the Chasm, Harper Collins, New York.

Moore, G. A., and R. McKenna, 2002. Crossing the Chasm: Marketing and Selling Technology Products to Mainstream Customers. HarperBusiness, New York.

Moore, J.R. 1969. "The technology transfer process between a large science-oriented and a large market-oriented company--the North American Rockwell challenge." IEEE Transactions on Engineering Management. EM-16 (3): 111-115.

Moore, J. S. “Industrially Sponsored University Research in Information Technology: Some Recommendations Regarding Intellectual Property Agreements,” July 23, 2002 (www.cra.org/Activities/snowbird/2002/slides/ip-memo.pdf).

Moore, R.F., "A Corporate-wide Technology Communication System," Vol. 15, No. 1, January, 1972, pp. 43-46.

More E. and H. Irwin 1995. "Technology-Transfer--Technocultures, Power And Communication--The Australian Experience." Journal of Information Science, 21(3): 149-159.

Morgan, E. J. and N. K. Crawford ?. "Technology transfer centres and local enterprise initiatives." International Journal of Technology Management, 3(3): 361-366.

Morgan, M. G. and R. M. White, R M. 1994. "A Design For New National Laboratories." Issues in Science and Technology, 10(2): 29-32.

Morone, J. and R. Ivins. 1982. "Problems and Opportunities in Technology Transfer from the National Laboratories to Industry. Research Management, 25(3) May, 35-44.

Mortenson, P. K. 1990. "Changing expectations--COSMIC in the New World." Journal of Technology Transfer, 15 (1 & 2): 67.

Mowery, D. C. "International Collaborative Ventures and the Commercialization of New Technologies," in Technology and the Wealth of Nations, N. Rosenberg, R. Landau, and D. Mowery, eds. (Stanford University Press, Palo Alto, California, 1992), Chapter 13.

Mowery, D. C. (1998). “Collaborative R&D: How Effective Is It?” Issues in Science and Technology, Vol. 15, No.1, pp. 37-44.

Mowery, David, Richard Nelson, Bhaven Sampat, and Arvids Ziedonis. 2001. “The Growth of Patenting and Licensing by U.S. Universities: An Assessment of the Effects of the Bayh-Dole Act of 1980.” Research Policy 30:99-119.

Mowery, David, and Bhaven Sampat. 2001. “Patenting and Licensing University Inventions: Lessons from the History of the Research Corporation.” Industrial and Corporate Change . 10: 317-355.

Mowery, David, and Bhaven Sampat. 2001. “University Patents, Patent Policies, and Patent Policy Debates: 1925-1980.” Industrial and Corporate Change. 10: 781-814.

Mowery, David, Bhaven Sampat, and Arvids Ziedonis. 2001. “Learning to Patent? Institutional Experience and the Quality of University Patents.” Management Science 48: 73-89.

Mowery D. C., and J.E. Oxiey and B. S. Silverman 1996. "Strategic alliances and interfirm knowledge transfer." Strategic Management Journal 17: 77-91.

Mowery D.C. and J. E. Oxiey 1995. "Inward Technology-Transfer And Competitiveness - The Role Of National Innovation Systems." Cambridge Journal Economics, 19(1): 67-93.

Mowery, D. C. and R. N. Langlois 1996. "Spinning off and spinning on(?): The federal government role in the development of the US computer software industry." Research Policy, 25(6): 947-966.

Mulkay, M. 1972. "The Social Process Of Innovation." (London: Macmillan).

Myers, W. (1998, April). Why software developers refuse to improve. IEEE Computer, 110-112.

N

Nataraajan, R. and S. K. Chawla 1994. "Random Transfer Of Technology - An Unexplored Phenomenon." Journal Technology Transfer, 19(1): 27-32.

National Academy of Sciences, National Academy of Engineering, Institute of Medicine, Committee on Science, Engineering, and Public Policy. 1991. Finding Common Ground: US Export Controls in a Changed Global Environment, Panel on the Future Design and Implementation of US National Security Export Controls. (Washington, DC: National Academy Press).

National Governors' Association 1983. Technology and Growth: State initiatives in technological innovation. (Washington, DC: National Governors Association.)

National Research Council, 1979. Technology Transfer: The Research Process and Creating a Productive Environment. (Washington, DC: National Academy Press) .

National Science Board (NSB). 2002. “Science & Engineering Indicators--2002.” (NSB-02-1) Arlington, VA: National Science Foundation.

National Science Foundation. 1975. "Federal Technology Transfer: An Analysis of Current Programs Characteristics and Practices." Washington, DC: National Science Foundation.

Nau, H. R. 1976. Technology Transfer and US Foreign Policy. (Praeger).

Nelson C. W. 1996. "From free money to free market." International Journal of Technology Management, 12(7-8): 748-759.

Nelson R. 1984. High-Technology Policies - A Five Nation Comparison. (Washington: AEI).

Nelson, Richard, and Bhaven Sampat. 2001. “Making Sense of Institutions as a Factor Shaping Economic Performance.” Journal of Economic Behavior and Organization 44:31-54.

Nelson, A. C., and Rottman, J. (1996). Before and after CASE adoption. Information & Management, 31, 193-202.

Nieuwenhuysen, P. and P. Vanouplines 1998. "Document+program hybrids on the Internet and their impact on information transfer." Online CDROM Review, 22(2): 55-72.

Niosi, J., P. Hanel, and L. Fiset 1995. "Technology-Transfer To Developing-Countries Through Engineering Firms--The Canadian Experience." World Development, 23(10): 1815-1824.

Norling, Parry M., Jan P. Herring, Wayne A. Rosenkrans, Jr., "Putting Competitive Intelligence to Work." Vol.43 No. 5, September-October 2000. pp 23

Nuckolls, J. 1994. "Lawrence Livermore: Commercial Spinoffs From Defense And Civilian Research And Development Programs." Forum for Applied Research and Public Policy, 9(Spring): 101-4.

O

Oakey, R. P., Hare, P. G., Balazs, K. 1990. "Diffusion of process innovations in an East European economy - some conceptual observations." Science & Public Policy, 17 (2): 97.

Office of Technology Policy, “Recent Trends in Federal Lab Technology Transfer: FY 1999-2000 Biennial Report,” U.S. Dept. of Commerce, May 2002. (http://www.ta.doc.gov/reports/TechPolicy/FedLabTechTrans.pdf)

Oik, P. and K. Xin 1997. "Changing the Policy on Government- Industry Cooperative R&D Arrangements: Lessons from the US Effort." International Journal of Technology Management, 13(7-8).

Oiken, H. 1987. "Technology transfer: starting your own high-tech business." International Journal of Technology Management, 2 (3-4): 543-44.

Oiken, Hyman, "Cooperation Between Private Industry and the National Laboratories," Vol. 28, No.2, March-April, 1985, p.6

O'Keefe, T.G. 1982. "Evaluation technology transfer: Some problems and solutions." Journal of Technology Transfer. 6(2): 53.

Olayan, H.B., 'Technology Transfer in Developing Nations," Vol. 42, No. 3, May-June, 1999, pp.43

Organization for Economic Cooperation and Development. 1984. Industry and University, New Forms of Cooperation and Communication. (Paris: OECD).

Orlikowski, W. J. (1993, September). CASE tools as organizational change: Investigating incremental and radical changes in systems development. MIS Quarterly, 17(3), 309-40.

Orlikowski, W. J., and Baroudi, J. J. (1991, March). Studying information technology in organizations: Research approaches and assumptions. Information Systems Research, 2(1), 1-28.

Orr, J. F. 1979. Technology transfer and the diffusion of innovations: a working bibliography with annotations. Organization for Economic Cooperation and Development. 1987. Reviews of National Science and Technology Policy: Netherlands. (Paris: OECD).

Overcoming Barriers to Collaborative Research, Report of a Workshop," Government-University-Industry Research Roundtable, National Academy Press, 1999. (http://www.nap.edu/books/0309067847/html/)

P

Pakes, A. and Schankerman, M. 1984. "The rate of obsolescence of patents, research gestation lags, and the private rate of return to research resources." in R&D, Patents and Productivity. Z. Griliches (ed.) (Chicago, IL: University of Chicago Press) 73-88.

Pandia, R.M. 1989."Transfer of technology: Techniques for chemical and pharmaceutical projects." Project Management. 20 (3) .

Papaconstantinou G., N. Sakurai and A. Wyckoff 1998. "Domestic and international product-embodied R&D diffusion." Research Policy, 27(3): 301-314.

Papadakis, M. 1995. "Federal Laboratory Missions. Products, and Competitiveness." Journal of Technology Transfer, 20(1): 54.

Papadakis, Mary C., "The Reality of Metrics and the Quest for Magic Bullets," in Rood, Sally A. and Louis G. Tornatzky, eds, Roundtable on Technology Transfer Metrics, Technology Transfer Society 22nd Annual Conference, 19-23.

Park, W. G. 1995. "International R&D Spillovers And OECD Economic Growth." Economic Inquiry, 33(October): 571-91.

Parker, D. D., D. Zilberman 1993. "University Technology Transfers - Impacts On Local And United-States Economies." Contemporary Policy Issues, 11(2): 87-99.

Pavitt, K. 1985. "Technology transfer amongst the industrially advanced countries: an overview." in International Technology Transfer. N. Rosenberg and R. Frischtak (eds.) (Praeger).

Pavitt, K. 1991. "What Makes Basic Research Economically Useful?" Research Policy, 20(2): 109.

Pavitt, K. 1992. "Internationalisation of technological innovation." Science & Public Policy, 19(2): 119.

Pearce, F. 1992. "The Hidden Cost Of Technology Transfer." New Scientist, 134(May 9): 36-9.

Pejovich, S. 1996. "Property-Rights And Technological Innovation." Social Philosophy & Policy, 13(2): 168-180.

Pensyi, M. 1990. "Emerging Roles for Academic Librarians in the Technology Transfer Process." Science & Technology Libraries, 11(2): 29.

Penzias, A.A., "Technology in the Coming Century," Vol. 42, No. 1, January-February, 1999, pp.52.

Perchorowicz, J. T., K. J. Dakin, & J. Lindsey. 1991. "Technology Transfer - Financing and Commercializing the High Tech Product or Service from Research to Roll Out." Journal of Technology Transfer, 16 (3): 62.

Peters, T., and Waterman, R. H., Jr. (1982). "In search of excellence: Lessons from America's best-run companies." Harper and Row, New York, NY.

Pfeffer, J., and Sutton, R. I. (2000). "The knowing-doing gap: How smart companies turn knowledge into action." Harvard Business School Press, Boston, MA.

Pfleeger, Shari Lawrence, "Understanding and improving technology transfer in software engineering," Journal of Systems and Software, vol. 47, 1999, pp 111-124.

Pianta, M. 1995. "Technology And Growth In OECD Countries, 1970- 1990"(Part Of Special Issue On Technology And Innovations). Cambridge Journal of Economics, 19(February): 175-87.

Pimentabueno, J. A. and R. T. Correa 1993. "A New Look At The United-States Pattern Of Federal Research-And-Development Spending--Preliminary Lessons For Newly Industrializing Economies." Technovation, 13(2): 101-107.

Pinelli, T. E., J. M. Kennedy, and R. 0. Barclay. 1990. "The Role of the Information Intermediary in the Diffusion of Aerospace Knowledge." Science & Technology Libraries, 11, (2): 59.

Pinelli, T. E., R. 0. Barclay and J. M. Kennedy "The United- States-Government Technical Report And The Transfer Of Federally Funded Aerospace R-And-D." Government Publications Review, 20(4): 393-411.

Piper, W. S. and S. Naghshpour 1996. "Government technology transfer: The effective use of both push and pull marketing strategies." International Journal of Technology Management, 12(1): 85-94.

Pope, K. 1992. "Getting Away From Military Technology." The Sciences, 32 (July/August): 28.

Portnow, J. 1994. "Technology Transfer and Assistive Devices for Disabled People at Home. Journal of Technology Transfer, 19 (2): 7.

Potter, B.V., "Effective Information and Technology Transfer in Multinational R&D," Vol. 14, No. 1, January, 1971, pp. 20-27.

Potworowski, J. A. 1991. "A Technology-Utilization Framework for Developing Countries." Journal of Technology Transfer, 16 (1): 33.

Powell W. W. and J. Owen-Smith 1998. "Universities and the marker for intellectual property in the life sciences." Journal of Policy Analysis and Management, 17(2): 253-277.

Premkumar, G., and Potter, M. (1995, May/August). Adoption of computer aided software engineering (CASE) technology: An innovation adoption perspective. Data Base for Advances in Information Systems, 26(2-3), 105-23.

Prescott, M. B. and S.A. Conger, 1995. "Information technology innovations: a classification by IT locus of impact and research approach, Data Base for Advances in Information Systems, 26(2/3), pp 20-41.

Press, E., and Washburn, J., "The Kept University," The Atlantic Monthly, March 2000, p.39.

Price, S. C., and P. Z. Sobocinski. (2001). “Gap Funding in the United States and Canada,” The Journal of the Association of University Technology Managers,Volume XIII. Prosser, G. A. 1995. "The Role of Incentives in the Deployment of Technologies from Cooperative Research and Development." Journal of Technology Transfer, 20(2): 13.

“Public Investments in University Research: Reaping the Benefits.” Report of the Expert Panel on the Commercialization of University Research, presented to The Prime Minister’s Advisory Council on Science and Technology. London, 1999.

Q

Quinn, J.B. 1969. "Technology transfer by multinational companies." Harvard Business Review, Nov-Dec.

R

Rabino, S. 1989. "High technology firms and factors influencing transfer of R&D facilities." Journal of Business Research. 18 (3).

Radosevich, R. 1995. "A Model For Entrepreneurial Spin-Offs From Public Technology Sources." International Journal of Technology Management, 10(7-8): 879-893.

Rahm, D. 1993. "United-States Public-Policy And Emerging Technologies--The Case Of Solar-Energy." Energy Policy, 21(4): 374-380.

Rahm, D. 1994. "Academic Perceptions Of University-Firm Technology-Transfer." Policy Studies Journal, 22(2): 267-278.

Rahm, D., B. Bozeman and M. Crow. 1988. "Domestic Technology Transfer and Competitiveness." Public Administration Review, 48: 969-78.

Rai, A. (1995, May). External information source and channel effectiveness and the diffusion of CASE innovations: An empirical study. European Journal of Information Systems, 4(2), 93-102.

Rai, A., and Howard, G. S. (1993, Summer). An organizational context for CASE innovation. Information Resources Management Journal, 6(3), 21-34.

Rai, A., and Howard, G. S. (1994, March). Propagating CASE usage for software development: An empirical investigation of key organizational correlates. Omega (Oxford), 22(2), 133-147.

Rai, A., and Patnayakuni, R. (1996, Fall). A structural model for CASE adoption behavior. Journal of Management Information Systems, 13(2), 205-34.

Ramiller, N. C. (1994, March). Perceived compatibility of information technology innovations among secondary adopters: Toward a reassessment. Journal of Engineering & Technology Management, 11(1), 1-23.

Randazzese, L. P. 1996. "Exploring university-industry technology transfer of CAD technology." IEEE Transactions On Engineering Management, 43(4): 393-401.

Rappa, M. A. and K. Debackere 1992. "Technological Communities And The Diffusion Of Knowledge." R&D Management, 22(3): 209-220.

Raut, L. K. 1995. "R&D Spillover And Productivity Growth-- Evidence From Indian Private Firms." Journal of Development Economics, 48(October): 1-23.

Ravichandran, T. (2000, Summer). Swiftness and intensity of administrative innovation adoption: An empirical study of TQM in information systems. Decision Sciences, 31(3), 691-724.

Ravichandran, T., and Rai, A. (2000, September). Quality management in systems development: An organizational system perspective. MIS Quarterly, 24(3), 381-6+405-10.

Raz, B., & Assa, I. 1988. "A model of coupled technology transfer: A logistic curve approach." Technological Forecasting and Social Change. 33:251-265.

Reams, B. 1986. University-Industry Research Partnerships: The Major Legal Issues In Research And Development Agreements. (Westport, CT: Quorum).

Rebentisch E. S. and M. Ferretti 1995. "A Knowledge Asset-Based View Of Technology-Transfer In International Joint Ventures." Journal of Engineering and Technology Management, 12(1-2): 1-25.

Reddy, N. Mohan and L. Zhao 1990. "International technology transfer: A review." Research Policy, 19: 285-307.

Redwine, S. T., Jr., Becker, L. G., Marmor-Squires, A. B., Martin, R. J., Nash, S. H., & Riddle, W. E. (1984, June). "DoD related software technology requirements, practices, and prospects for the future." (P-1788). Institute for Defense Analysis, Alexandria, VA.

Redwine, Samuel, and William E. Riddle, 1985. “Software technology maturation.” Proceedings of the Eighth International Conference on Software Engineering, IEEE Computer Society Press, Los Alamitos, California, pp 189-200.

Reid, P. P. and A. Schriesheim, eds. 1996. Foreign Participation in US Research and Development: Asset or Liability. (Washington, DC: National Academy Press).

Reid, P. P. and A. Schriesheim, eds. 1996. Prospering in a Global Economy: Foreign Participation in US Research and Development. (Washington, DC: National Academy Press).

Reingold, N. 1994. "Science And Government In The United-States Since 1945." History Of Science, 32(98, part 4): 361-386.

Reisman, A. 1989. "Technology transfer: A taxonomic view." Technology transfer. Summer-Fall.

Reisman, A. and L. Zhao. 1991. "A Taxonomy of Technology- Transfer-Transaction Types." Journal of Technology Transfer, 16(2): 38.

Repenning, N. P. (2002, March-April). A simulation-based approach to understanding the dynamics of innovation implementation. Organization Science, 13(2), 109-127.

Rhea, John, "Prospecting for Science in the Former Soviet Union," Vol. 35, No.6, November-December, 1992, pp. 13-17

Rheingold, N. and M. Rothenberg (eds.) 1987. Scientific Colonialism: A Cross-Cultural Comparison. (Washington, DC: Smithsonian Institution Press).

Richardson, G. P. (1991). "Feedback thought in social science and systems theory." University of Pennsylvania Press, Philadelphia, PA.

Rifkin, S. (2001, July/August). Why software process innovations are not adopted. IEEE Software, 10(4), 110-112.

Rifkin, S. (2001, May/June). What makes measuring software so hard? IEEE Software, 10(3), 41-45.

Risen, J., & Johnston, D. (2002, September 8). Not much has changed in a system that failed: The F.B.I. and C.I.A. missed signals a year ago. Now they do well in capital turf wars. New York Times, Section 4, p. 1.

Robb, Walter L. “How Good is Our Research?, Research Technology Management, March/April 1991.

Roberts, T. L., Gibson, M. L., Rainer, R. K., and Fields, K. T. (2001, March). Response to 'Comments on factors that impact the implementation of a systems development methodology'. IEEE Transactions on Software Engineering, 27(3), 282-286.

Roberts, T. L., Jr., Gibson, M. L., Fields, K. T., and Rainer, R. K., Jr. (1998, August). Factors that impact implementing a system development methodology. IEEE Transactions on Software Engineering, 24(8), 640-649.

Robertson, N.C., 'Technology Acquisition for Corporate Growth," Vol. 35, No. 2,March-April, 1992, pp. 26-30

Roessner, D., Ailes, C., Feller, I. and Parker, L., "How Industry Benefits from NSF's Engineering Research Centers," Vol. 41, No. 5, September-October, 1998., pp. 40.

Roessner, J. D. and A. Bean. 1991. "How Industry Interacts with Federal Laboratories." Research Technology Management, 34(4): 22.

Roessner, J. D. and A. S. Bean 1993. "Industry Interaction With Federal Labs Pays Off." Research Technology Management, 36(5): 38-40.

Roessner, J. D. and A. Wise 1994. "Public-Policy And Emerging Sources Of Technology And Technical-Information Available To Industry." Policy Studies Journal, 22(2): 349-358.

Roessner, J. D. “Patterns of Industry Interaction with Federal Laboratories.” School of Public Policy, Georgia Institute of Technology, Atlanta. March 1993, p. 8.

Rogers, E. M. (1995) Diffusion of innovations (4th ed.). The Free Press, New York.

Rogers, E. M. and F. F. Shoemaker. 1971. Communication of Innovations: A Cross Cultural Approach.(New York: Free Press).

Romo, J., & Roecks, A. 1988. "Transferring technology transfer into an Air Force unit." Technology Transfer. 54-57.

Rosenberg, N. 1987. "Civilian 'spillovers' from military R&D spending: The U.S. experience since World War II." in Strategic Defense and the Western Alliance. S. Lakoff and R. Willoughby (eds.) (Lexington, MA: D.C. Heath and Co.).

Rosenberg, N. and C. Frischtak, eds. 1985. International Technology Transfer: Concepts, Measures And Comparisons. (New York, NY: Praeger).

Rosenberg, N. and W. G. Vincenti. 1978. The Britannia Bridge: The Generation And Diffusion Of Technological Knowledge. (Cambridge, MA: MIT Press.).

Rosenbloom, R.S. 1965. Technology transfer-- process and policy: an analysis of the utilization of technological by-products of military and space R&D. (Washington: National Planning Association.) Special Report No. 62.

Roth, G., and Kleiner, A. (2000). "Car launch: The human side of managing change." Oxford University Press, New York, NY.

Rothwell, R. 1978. "Some problems of technology transfer into industry: Example from the textile machinary sector." IEEE Transactions on Engineering Management. EM-25 (Feb): 15-19.

Rothwell, R. and M. Dodgson 1992. "European Technology Policy Evolution--Convergence Towards SMEs and Regional Technology- Transfer." Technovation, 12(4): 223-238.

Rubin, M. 1991. "How Organizations Form R&D Consortia." Journal of Technology Transfer, 16 (I): 19.

Russell, A. 1995. "Merging technological paradigms and the knowledge structure in international political economy." Science & Public Policy, 22 (2): 106.

Russo, J. & R. C. Herrenkohl. 1990. "Factors Affecting the Transfer of Technology from Industry/University Cooperatives to Sponsoring Companies." Journal of Technology Transfer, 15(3): 21.

Ryan, T. F., and Bock, D. B. (1992, November). A socio-technical systems viewpoint to CASE tool adoption. Journal of Systems Management, 43(11), 25-9.

S

Sagie, A., Elizur, D., and Greenbaum, C. W. (1985, April). Job experience, persuasion strategy and resistance to change: An experimental study. Journal of Occupational Behaviour, 6(2), 157-162.

Sahal, D, ed. 1982. The Transfer and Utilization of Technical Knowledge. Lexington, MA: Lexington Books.

Sahal, D. 1982. "The form of technology governs the scope of its transfer" in D. Sahal (ed.) The transfer and utilization of technical knowledge. (Lexington, MA: Lexington.)

Salomon, J-J. 1995. "The uncertain quest--mobilising science and technology for development." Science & Public Policy, 22(1): 9.

Sanders, J D. 1994. "Transfer or ?." Journal of Technology Transfer, 19(2): 3.

Sanzmenendez, L. 1995. "Policy Choices, Institutional Constraints And Policy Learning - The Spanish Science And Technology Policy In The Eighties." International Journal of Technology Management, 10(4-6): 622-641.

Sapienza, A.M. 1989. "Technology transfer: An assessment of the major institutional vehicles for diffusion of U.S. biotechnology." Technovation. 9(6).

Scarso E., and E. Bolisani 1996. "Technology transfer to supplier-dominated sectors: Lessons from the diffusion of CAD in the fashion industry." International Journal of Technology Management, 12(4): 421-437.

Scheirer, M. 1983. "Approaches to the study of implementation." IEEE Transactions on Engineering Management. EM-30 (May): 76-82.

Scherer, F. 1982. "Interindustry technology flow in the USA." Research Policy, 11: 227.

Schiff, S. H. 1995. "Future Missions For The National Laboratories." Issues in Science and Technology, 12(1): 28-30.

Schmid, L.C. 1989. A report to the congress and the federal agencies: Activities and accomplishments of the Federal Laboratory Consortium for Technology Transfer Pursuant to the Federal Technology Transfer Act of 1986. A report by Federal Laboratory Consortium for Technology Transfer.

Schmitt, R.W., 'Technology Export Defining Priorities," Vol. 25, No. 5,September, 1982, pp. 7-8

Schmoch, U. 1993. "Tracing The Knowledge Transfer From Science To Technology As Reflected In Patent Indicators." Scientometrics, 26(1): 193-211.

Schneiderman, R. 1989. "Profitable Technology From Uncle Sam." High Technology Business, 9(February): 26-30.

Schoenecker, T.S., D. Myers, and P. Schmidt 1989. "Technology transfer at land-grant universities." Technology Transfer. Spring.

Schott, T. 1994. "Collaboration In The Invention Of Technology-- Globalization, Regions, And Centers." Social Science Research, 23(1): 23-56.

Schouder, W., A. Nashar and V. Padmanabhan. 1990. "A Guide to the Best Technology-Transfer Practices." Journal of Technology Transfer 15(1-2): 5.

Schriesheim, A. 1990. "Toward a Golden Age for Technology Transfer." Issues in Science & Technology 7(2): 5258.

Schriesheim, A. 1994. "Argonne: Transfer Of Discoveries To Industry." Forum for Applied Research and Public Policy, 9(Spring): 98-100.

Schriesheim, A. 1994. "The Changing Role Of The National Laboratories: Man Bites Dog." Chemtech, 24(February): 33-4.

Schroer, B. J., M. C. Ziemke, P. A. Farrington, R. J. Sampson. 1994. "The Chamber of Commerce - A New Proactive Factor in Technology Transfer." Journal of Technology Transfer, 19 (2): 34.

Schroer, B. J., P. A. Farrington, S. L. Messimer, and J. R. Thornton. 1995. "Measuring Technology Transfer Performance." Journal of Technology Transfer, 20(2): 39.

Schumpeter, J. A. (1939). "Business cycles: A theoretical, historical, and statistical analysis of the capitalist process." McGraw-Hill, New York, NY.

Schumpeter, J. A. (1942). "Capitalism, socialism, and democracy." Harper & Row, New York, NY.

Scientific American 1987. "Technology for sale: The federal technology transfer act of 1986." Scientific American. 256: 62 May.

Seaton, R. A. and M. Cordeyhayes 1993. "The Development And Application Of Interactive Models Of Industrial-Technology Transfer." Technovation, 13(1): 45-53.

Sedaitis, J. B. 1996. "Waking the sleeping giants: Commercializing state R&D in the United States and Russia." Technological Forecasting and Social Change, 53(3): 293-308.

Sen, F. and A.H. Rubenstein 1989. "External technology and in- house R&D's facilitative role." Journal of Product Innovation Management. 6(2).

Senge, P. M. (1990). "The fifth discipline: The art & practice of the learning organization." Currency Doubleday, New York, NY.

Senge, P., and et al. (1999). "The dance of change: The challenges of sustaining momentum in learning organizations." Currency Doubleday, New York, NY.

Seror, A. C. 1996. "Action research for international information technology transfer: A methodology and a network model." Technovation, 16(8): 421-429.

Serpa, Roy. 1992. "A Systematic Approach to Technology Transfer." Journal of Technology Transfer, 17 (4) pp 16.

Sexton, D. L. and S. M. Camp. 1992. "Technology Transfer and Value Creation." Journal of Technology Transfer, 17 (2 & 3): 68.

Shampine, A. 1998. "Compensating for information externalities in technology diffusion models." American Journal Of Agricultural Economics, 80(2): 337-346.

Shapira, P. 1990. "Modern times: learning from state-initiatives in industrial extension and technology transfer." Economic Development Quarterly. 4(3).

Shapley, D. 1993. "Clintonizing Science Policy." The Bulletin of the Atomic Scientists, 49(December): 38-43.

Sharif M. N. 1997. "Technology strategy in developing countries: evolving from comparative to competitive advantage." International Journal of Technology Management, 14(2-4): 309-343.

Sharp, R. 1984. "Systems Approach To Appropriate Technology Transfer"(Book Review). New Scientist, 102 (April 26): 46.

Shaw, B.T. 1989. "In support of strategies for technology assistance programs: Assisting small and medium sized manufacturers." Economic Development Review. 7 (1).

Sheen, M. 1992. "Barriers to Scientific and Technical Knowledge Acquisition in Industrial R&D." R&D Management, 22(2): 135.

Sherman, W. R. & W. G. Tymon. 1992. "The Unfulfilled Promise of an Envisioned Jewel - An Attempt to Transfer Technology Out of the Splintering Soviet Union." Journal of Technology Transfer, 17(4): 20.

Shi, X. P. 1995. "Patent Licensing For Technology-Transfer - An Integrated Structural Model For Research." International Journal of Technology Management, 10(7-8): 921-940.

Shim, S. J. (1998). Characteristics and adoption of generic financial expert systems: A case study of failure. Journal of Information Technology Management, 9(3), 43-51.

Sigurdson, J. 1992. "Internationalising research and development in Japan." Science & Public Policy, 19(3): 134.

Silberman, J. M., C. Weiss and M. Dutz 1996. "Marshall Plan Productivity Assistance: A unique program of mass technology transfer and a precedent for the former Soviet Union." Technological Society. 18(4): 443-460.

Silva, J., & Backhouse, J. (1997). Becoming part of the furniture: The institutionalization of information systems. In "Information systems and qualitative research (Proceedings of the IFIP TC8 WG 8.2 International Conference on Information Systems and Qualitative Research, May 31- June 3, 1997, in Philadelphia, Pennsylvania USA)" (A. S. Lee, J. Liebenau, and J. I. DeGross, Eds.), Chap. 20, pp. 389-414. Chapman & Hall, London.

Simon, T. W. and A. E. Wiens 1993. "Narratives Of Technology- Transfer." Bulletin Of Science Technology & Society, 13(2): 63- 66.

Singh, K. 1990. "Technology Development--A Holistic Perspective Involving Different National Communities." International Social Science Journal, 42(November): 593-604.

Sink, C. H. & K. Easley. 1994. "The Basis for US Department of Energy Technology Transfer in the 1990s." Journal of Technology Transfer, 19 (2): 52.

Sirilli, G. 1992. "Technological balance of payments as an indicator of technology transfer." Science & Public Policy, 19 (6): 347.

Sirleu, N.A. 1978. "Government Aid for the Development of Innovative Technology: Lessons from the French," Research Policy, 7: 176-196.

Skolnikoff, E. B. 1967. Science, Technology and American Foreign Policy. Cambridge, MA: MIT Press.

Skolnikoff, E. B. 1993. "New international trends affecting science and technology." Science & Public Policy, 20 (2): 115.

Skolnikoff, E. B. 1993. The Elusive Transformation: Science, Technology, And The Evolution Of International Relations. (Princeton, NJ: Princeton University Press).

Skolnikoff, E. B. 1995. "Evolving US science and technology policy in a changing international environment." Science & Public Policy, 22 (2): 74.

Slaughter, S. and G. Rhoades 1996. "The Emergence Of A Competitiveness Research-And-Development Policy Coalition And The Commercialization Of Academic Science And Technology." Science Technology & Human Values, 21 (3): 303-339.

Slowinski, Gene, Susan A. Atanton, John C. Tao, Wayne Miller, Donald P. McConnell, "Acquiring External Technology." Vol. 43, No.5, September-October, 2000, pp. 29.

Smilor, R and D Gibson. 1991. "Accelerating Technology Transfer in R&D Consortia." Research Technology Management, 34(I): 44.

Smilor, R. W., G. B. Dietrich and D. V. Gibson 1993. "The Entrepreneurial University: The Role Of Higher Education In The United States In Technology Commercialization And Economic Development." International Social Science Journal, 45(February): 1-11.

Smilor, R.W. 1987. "Commercializing Technology Through New Business Incubators." Research Management, 30(5): 36.

Smith, D. E. 1992. "Expert Systems for Medical Diagnosis - A Study in Technology Transfer." Journal of Technology Transfer, 17(4): 45.

Smith, R.W. 1987. "Commercializing Technology Through New Business Incubators." Research Management, 30(5): 36.

Soderstrom, J. and B. Winchell. 1986. "Patent Policy Changes Stimulating Commercial Application of Federal R&D." Research Management, 29(3): 35-39.

Souder W. E., N. C. Schoening and M. S. Spann 1996. "Commercial spin-offs from government laboratories and regional economic development: The Huntsville, Alabama story." Journal Of Scientific & Industrial Research, 55(4): 223-233 APR 1996

Souder, W. E., A. S. Nashar, & V. Padmanabhan. 1990. "A Guide To the Best Technology-Transfer Practices." Journal of Technology Transfer, 15(1 & 2): 5.

Souder, W.E. and V. Padmanabhan 1989. "Transferring new technologies from R&D to manufacturing." Research-Technology Management. 32(5) pp. 38-43.

Southon F. C. G., C. Sauer C, and C. Dampney 1997. "Information technology in complex health services: Organizational impediments to successful technology transfer and diffusion." Journal Of The American Medical Informatics Association, 4(2): 112-124.

Spann, M. S., M. Adams and W. E. Souder 1995. "Measures Of Technology-Transfer Effectiveness--Key Dimensions And Differences In Their Use By Sponsors, Developers And Adopters." IEEE Transactions On Engineering Management, 42(1): 19-29.

Spilka, R. (1995, August). Communicating across organizational boundaries: A challenge for workplace professionals. Technical Communication, 42(3), 436.

Spivey, W. A., J. M. Munson, W. T. Flannery. 1994. "Understanding the Environs that Impact Technology Transfer and Transition." Journal of Technology Transfer, 19(2): 63.

Spivey, W. A., Munson, J, Michael, Flannery, William T. 1990. "Interest in Technology Transfer across Academic Disciplines - Publication Trends, 1981 thru 1989." Journal of Technology Transfer, 15(3): 13.

Starr, C. 1985. "Industrial Cooperation in R&D." Research Management, 28(5):13-16.

Steele, L.W., "Barriers to International Technology Transfer," Vol. 17, No. 1, January, 1974, pp. 17-21.

Stein, B. A., and Kanter, R. M. (1993, November). Why good people do bad things: A retrospective on the Hubble fiasco. The Academy of Management Executive, 7(4), 58.

Stein, B. A., and Kanter, R. M. (1993, Winter). Leadership for change: The rest of the story. Frontiers of Health Services Management, 10 (2 Page: 28).

Stevens, G. A, and J. Burley, May-June 1997, “3000 Raw Ideas = 1 Commercial Success: Significant odds facing would-be innovators are confirmed by an analysis of consistent data from new product development, patenting activity and venture capital experience.” Research-Technology Management, pp. 16-27.

Stevens, J. H., L. B. Swim, J. D. Harmon. 1991. "Finance, Technology Transfer, and National Security - A Preliminary Survey." Journal of Technology Transfer, 16(3): 38.

Stevenson-Wyder Technological Innovation Act 1980. Public Law 96-480, Title 15, Section 3701-3714.

Stevenson-Wydler Technology Innovation Act of 1980, P.L. 96-517, United States Code, Title 15, Section 3701-3714.

Stevenson-Wydler Technology Innovation Act, 1984.

Stewart, C. T. Technology transfer and human factors. Lexington, MA: Lexington Books, 1987.

Stewart, J. D., J. R. Richburg and D. L. Goetsch 1995. "Technology Transfer From The Bottom Up." Forum for Applied Research and Public Policy, 10(Winter): 40-3.

Stobaugh, R. and Well Jr., L.T. (eds) 1984. Technology crossing borders. (Boston: Harvard Business School Press.)

Storper, M. 1995. "Regional Technology Coalitions: An Essential Dimension of National Technology Policy." Research Policy, 24(6): 895-913.

Supapol, A. B. 1990. "The commercialization of government- sponsored technologies: Canadian evidence." Research Policy, 19: 369-378.

Swanson, D. H. 1995. "Determining the Government's Responsibilities in Technology." Journal of Technology Transfer, 20(2): 3.

Swanson, E. B. (1988). "Information system implementation: Bridging the gap between design and utilization." Irwin, Homewood, IL.

Swanson, E. B. (1994, September). Information systems innovation among organizations. Management Science, 40(9): 1069-1092.

Swanson, E. B., and Ramiller, N. C. (1997, September-October). The organizing vision in infromation systems innovation. Organization Science, 8(5): 458-474.

Swyt, D. 1988. "Transferring NBS technology to small manufacturers through state and local centers." Technology Transfer. 7-13.

Szakonyi, Robert, "101 Tips for Managing R&D More Effectively," Vol. 33, No. 4,July-August, 1990, pp. 31-36; November-December, 1990, pp. 41-46

T

2002 Conference Proceedings of the National Energy Technology Laboratory "Technology Partnerships 2002 Best Practices" Conference, June 11-13, 2002. (http://www.netl.doe.gov/publications/proceedings/02/transpartner/trans02.html#Papers)

Tait, P., and Vessey, I. (1988, March). The effect of use involvement on system success: A contingency approach. MIS Quarterly, 91-108.

Talaysum, A.T., "Understanding the Diffusion Process for Technology Intensive Products," Vol. 28, No. 4, July-August, 1985, pp. 22-26

Tann, J. 1996. "Technology transfer - Getting from here to there: From 'know how' to 'how to'." Interdisciplinary Science Review 21(3): 215-220.

Tassey, Gregory, 2000, "Standardization in Technology-Based Markets," Research Policy, 29, 587-602.

Tech Transfer Bill Approved." 1996. Issues in Science and Technology, 12(Spring): 27-8.

Technology and Information Policy Program, 1985. Technology and knowledge transfer: A case study of Brookhaven National Laboratory. Working Paper (85-023), Technology and Information Policy Program.

Technology Transfer by Stock Exchanges." 1995. Nature, 375(June 15): 521-2.

Teece, D.J. 1977. "Technology transfer by multinational firms: The resource cost of transferring technological know-how." The Economic Journal. June: 242-261.

Tenkasi, R. V. & S. A. Mohrman 1995. "Technology Transfer as Collaborative Learning." NIDA Research Monograph, 155: 147.

Thursby, Jerry G. and Marie C. Thursby, 2002. "Are faculty critical? Their role in university-industry licensing," unpublished paper, October.

Thursby, Jerry G. and Marie C. Thursby, 2002. "Buyer and seller views of university/industry licensing," unpublished paper, October.

Thursby, Jerry G. and Marie C. Thursby, 2002. “University licensing under Bayh-Dole: What are the issues and evidence?,” Paper prepared for the President’s Council of Advisors on Science and Technology, February.

Thursby, Jerry G. and Marie C. Thursby, 2002. “Who is selling the ivory tower? Sources of growth in university licensing,” Management Science, 48(1), January, pp 90-104.

Thursby, Jerry G., Richard Jensen and Marie C. Thursby, 2001. “Objectives, characteristics and outcomes of university licensing: a survey of major U.S. universities,” Journal of Technology Transfer, vol. 26, pp 59-72.

Tilton, J. 1971. International Diffusion of Technology: The Case of Semi-Conductors. Washington, DC: Brookings Institution.

Tornatzky, L. G. 1995. "Technology Policy and Programs at a Crossroads." Journal of Technology Transfer, 20(1): 4.

Tornatzky, L. G., and Fleischer, M. (1990). "The processes of technological innovation." Lexington Books, Lexington, MA.

Tornatzky, L. G., and Klein, K. J. (1982, February). Innovation characteristics and innovation-implementation: A meta-analysis of findings. IEEE Transactions on Engineering Management, EM-29(1), 28-45.

Tornatzky, L. G., M. Fleischer, and R. Drazin 1991. "The Processes of Technological Innovation." Journal of Technology Transfer, 15(1 & 2): 45.

Tornatzky, Louis G, Paul G. Waugman, and Denis O. Gray, 2002. Innovation U.: New University Roles in a Knowledge Economy, Southern Growth Policies Board, Research Triangle, North Carolina.

Triana, E. 1989. "Technology parks and technology transfer." International Journal of Technology Management. 4(4-5): 431-40.

Trott, P. and M. Cordeyhayes,1996. "Developing A Receptive R-And- D Environment For Inward Technology Transfer--A Case-Study Of The Chemical-Industry." R&D Management, 26(1): 83-92.

Trott, P., M. Cordeyhayes and R. A. Seaton 1995. "Inward Technology-Transfer As An Interactive Process." Technovation, 15(1): 25-43.

Tsang, E. 1994. "Strategies For Transferring Technology To China." Long Range Planning, 27(3): 98-107.

Turpin, T., S. Garrettjones and N. Rankin 1996. "Bricoleurs And Boundary Riders--Managing Basic Research And Innovation Knowledge Networks." R&D Management, 26(3): 267-282.

Tushman, & Scanlan, T. 1981. "Boundary spanning individuals: Their role in information transfer and their antecedents." Academy of Management Journal. 24: 289-305.

Tushman, M. L., and Anderson, P. (1986). Technological discontinuities and organizational environments. Administrative Science Quarterly, 31, 439-465.

Tushman, M. L., and Rosenkopf, L. (1992). Organizational determinants of technological change: Toward a sociology of technological evolution. Organizational Behavior, 14, 311-347.

Tushman, M., & Scanlan, T. 1981 "Characteristics and external orientations of boundary spanning individuals." Academy of Management. 24: 83-98.

Tyre, M. J., and Orlikowski, W. J. (1994, July). The myth of continuous improvement. Chemtech, 24, 12-19.

U

U.S. Congress, Office of Technology Assessment (April, 1986). “Research Funding as an Investment: Can We Measure the Returns? -- A Technical Memorandum,” Washington, DC, OTA-TM-SET-36.

U.S. Department of Commerce (September, 2002). “Summary Report on Federal Laboratory Technology Transfer – Agency Approaches; FY 2001 Activity Metrics and outcomes,” Washington, DC.

Uniform Patent Procedures Act of 1983. 1984. Public Law 98-620 enacted November 8, 1984.

US Congress, Office of Technology Assessment. 1990. Agricultural Research and Technology Transfer Policies for the 1990's, OTA-F- 447. (Washington, DC: USGPO).

US Congress. 1984. Stevenson-Wydler Technology Innovation Act of 1980. United States Code, Title 15, Section 3701-3714: 96-517. (Washington, DC: USGPO).

US Congress. 1986. Federal Technology Transfer Act of 1986. 99th Congress, 2nd Session (Washington, DC: USGPO).

US General Accounting Office. 1983. The Federal Role in Fostering University-Industry Cooperation. (Washington, DC: USGPO).

US General Accounting Office. 1989. Technology transfer: Implementation status of the federal technology transfer act of 1986.

Utterback, J. 1979. "Innovation in industry and the diffusion of technology." Science, 183 (15 February): 620-626.

V

Van Dierdonck, R., K. Debackere and M. Rappa. 1991. "An Assessment of Science Parks: Towards a Better Understanding of their Role in the Diffusion of Technological Knowledge." R&D Management, 21(2): 109.

Varzaly, L., & Elashmawi.F. 1984. "Technology utilization: The new corporate challenge." Journal of Technology Transfer. 9: 61- 69.

Venanzi, D. 1996. "A new approach to the identification and selection of international technology transfer modes: Logical framework and empirical evidence." Technovation, 16(6): 287-300.

Venkatesh, V., Smith, R. H., and Morris, M. G. (2000, March). Why don't men ever stop to ask for directions? Gender, social influence, and their role in technology acceptance and usage behavior. MIS Quarterly, 24(2), 115-18+131-6.

Verma, S. K. 1996. "TRIPS - Development and transfer of technology." lie-International Review Of Industrial Property And Copyright Law, 27(3): 331-364.

Verspagen, B. 1997. "Estimating international technology spillovers using technology flow matrices." Weltwirtschaftliches Archiv-Review Of World Economics, 133(2): 226-248.

Vester, John, Lessons Learned About Integrating Acquisitions., Vol. 45, No. 3,May-June, 2002, pp. 33-41.

Vickery, G. 1986. "International flows of technology: Recent trends and developments." STI Review, 1: 47-83.

Vickery, G. 1987. "Diffusing new technologies: microelectronics." STI Review. (Sept): 41-80.

Vonortas, Nicholas S. (2002) "Partnerships and Networking in Science and Technology for Development," Technology for Development Paper Series, United Nations Conference on Trade and Development, Geneva: UNCTAD, 2002 (UNCTAD/ITE/TEB/11).

Vontunzelmann, G. N. 1994. "Technology-Transfer And Scandinavian Industrialization - Bruland. K." Research Policy, 23(3): 352-353.

W

Wagner, C. K. 1998. "Biotechnology in Mexico: placing science the service of business." Technology in Society, 20(1): 61-73.

Wartik, S., and Davis, T. (1999, April). A phased reuse adoption model. Journal of Systems & Software, 46(1), 13-23.

Watkins, C. 1985. "Technology transfer from university research in regional development strategies.' Journal of Technology Transfer, 10: 51-64.

Watkins, T. 1990. "Beyond Guns and Butter: Managing Dual-Use Technologies." Technovation, 10(6): 389.

Wei, L. 1995. "International Technology-Transfer And Development Of Technological Capabilities - A Theoretical Framework." Technology in Society, 17(1): 103-120.

Weick, K. (1979). "The social psychology of organizing." (2nd ed.) Wiley, New York.

Weijo, M.O. 1987. "Strategies for promoting technology transfer to the private sector." Journal of Technology Transfer. 11(2).

Werner, J. and J. Bremer. 1991. "Hard Lessons in Cooperative Research." Issues in Science & Technology, 7(3): 44-49.

Werner, Jerry, "Technology Transfer in Consortia," Research-Technology Management. Vol. 35, No. 3, May-June, 1992, pp. 38-43

Westmacott, T.I., "Culture, Capital, and Communications," Vol. 42, No. 1,January-February, 1999, pp. 48

White House Science Council. 1983. Report of the Federal Laboratory Review Panel: Packard Report. (Washington, DC: USGPO).

White, William, "Effective Transfer of Technology from Research to Development," Research-Technology Management. Vol. 20, No. 3, May, 1977, pp. 30-34

Wible, J. R. 1995. "The Economic-Organization Of Science, The Firm, And The Marketplace." Philosophy Of The Social Sciences, 25(1): 35-68.

Wigand, R. and G. Frankwick 1989. "Interorganizational communication and technology transfer: industry-government- university linkages." International Journal of Technology Management, 4(1): 63-76.

Wilde, D. U. & N. R. Cooper 1990. "Federal Laboratories & American Industry - Fueling Innovation." Journal of Technology Transfer, 15(1 & 2)1/2: 47.

Williams, L. R., and Rao, K. (1997). Information technology adoption: Using classical adoption models to predict AEI software implementations. Journal of Business Logistics, 18(2), 43-54.

Williams, L., Kessler, R. R., Cunningham, W., and Jeffries, R. (2000, July/August). Strengthening the case for pair programming. IEEE Software, 17(4), 19-25.

Williams, R. S., Senate Committee on Commerce, Science, and Transportation, Subcommittee on Science, Technology, and Space, post-Hearing questions for Dr. R. Stanley Williams, from Senator Ron Wyden, Hearing on Nanotechnology, Washington, D.C., September 17, 2002.

Winebrake, J. J. 1992. "A Study of Technology-Transfer Mechanisms for Federally Funded R&D." Journal of Technology Transfer, 17 (4): 54.

Winner. L. 1980. "Do Artifacts Have Politics?" Daedalus, 109.

Winpisinger, W.W., "The Case Against Exporting U.S. Technology," Research-Technology Management. Vol. 21, No.2, March, 1978, pp. 19-21.

Winter, M. 1997. "New policies and new skills: Agricultural change and technology transfer." Sociologia Ruralis, 37(3): 363.

Wolek, F. W. 1992. "Rip-off Transfers - Source of Social Progress." Journal of Technology Transfer, 17 (2 & 3): 51.

Wolfe, R. A. (1994, May). Organizational innovation: Review, critique and suggested research directions. Journal of Management Studies, 31(3), 405-431.

Wolff, M.F. 1989. "Technology transfer: A GM manager's strategy. Research-Technology Management. 32(5).

Wolff, M.F., "Plugging Into Overseas Technology," Research-Technology Management. Vol. 31, No. 2, March-April, 1988, pp.9-11.

Wolff, M.F., "Plugging Into Overseas Technology: 1990," Research-Technology Management. Vol. 33, No. 2, March-April, 1990, pp. 8-10.

Wolff, M.F., "Scouting for Technology," Vol. 35, No. 2, March-April, 1992, pp. 10-12

Wood S. C. and G. S. Brown 1998. "Commercializing nascent technology: The case of laser diodes at Sony." Journal of Product Innovation Management, 15(2): 167-183.

Woods, D. L. 1990. "American Libraries and Domestic Technology Transfer. Science & Technology Libraries, 11(2): 39.

Wright, D. J. 1993. "International Technology-Transfer With An Information Asymmetry And Endogenous Research-And-Development." Journal of International Economics. 35(1-2): 47-67.

Wyckoff, A. and L. Tornatzky 1988. "State-level efforts to transfer Manufacturing technology: a survey of programs and practices." Management Science, 14: 469-481.

Y

Yadav, S. B., Shaw, N. G., Webb, L., and Sutcu, C. (2001, March). Comments on 'Factors that impact implementing a system development methodology'. IEEE Transactions on Software Engineering, 27(3), 279-281.

Yang, H.-L. (1999). Adoption and implementation of CASE tools in Taiwan. Information & Management, 35(2), 89-112.

Yin, J Z. 1992. "Technological Capabilities as Determinants of the Success of Technology Transfer Projects." Technological Forecasting and Social Change 42(1): 17-30. Management, 39(5): 26-30.

Yong, S. and R. Gaertner 1994. "Technology Transfer From University To Industry: A Large-Scale Experiment With Technology Development And Commercialization (Part Of A Symposium On - Technology Transfer And Public Policy). Policy Studies Journal, 22 (2): 384-99.

Yoshikawa, A. 1988. "Technology transfer and national science policy: biotechnology policy in Japan." International Journal of Technology Management, 3 (6): 735-44.

Yoshikawa, A. 1990. "Japanese Biotechnology - Government, Corporations, and Technology Transfer." Journal of Technology Transfer, 15, (1 & 2): 53.

Yoxen, E. J. 1984. "Scepticism about the Centrality of Technology Transfer." Social Studies of Science, 14(2).

Yu H. Y. and K. S. Yeh 1996. "Technology transfer in Taiwan's information industry: The lessons." Research Technology

Yuan, J. D. 1996. "United States technology transfer policy toward China: Post-Cold War objectives and strategies." International Journal, 51(2): 314-338.

Z

Zelkowitz, M. V. (1996, August). Software engineering technology infusion within NASA. IEEE Transactions on Engineering Management, 43(3), 250-61.

Zelkowitz, Marvin V., 1995, "Assessing software engineering technology transfer within NASA," NASA technical report NASA-RPT-003095. National Aeronautics and Space Administration, Washington, DC.

Zelkowitz, Marvin V., Dolores Wallace and David Binkley, 1998, "Understanding the culture clash in software engineering technology transfer, " University of Maryland Computer Science Department technical report, 2 June.

Zhao, L. M. 1997. "International technology-transfer negotiations: towards a win-win strategy." International Journal of Technology Management, 14(2-4): 287-296.

Zhao, L. M. and A. Reisman 1992. "Toward Meta Research On Technology-Transfer." IEEE Transactions On Engineering Management, 39(1): 13-21.

Zigurs, I., DeSanctis, G., and Billingsley, J. (1991, Spring). Adoption patterns and attitudinal development in computer-supported meetings: An exploratory study with SAMM. Journal of Management Information Systems, 7(4), 51-70.

Zmud, R. W. (1982, December). Diffusion of modern software practices: Influence of centralization and formalization. Management Science, 28(12), 1421-1431.

Zmud, R. W. (1983, June). The effectiveness of external information channels in facilitating innovation within software development groups. MIS Quarterly, 16, 43-58.

Zmud, R. W. (1984, June). An examination of "push-pull" theory applied to process innovation in knowledge work. Management Science, 30(6), 727-738.

CF-187-OSTP

ISBN 0-8330-3359-X

52500

9 780833 033598