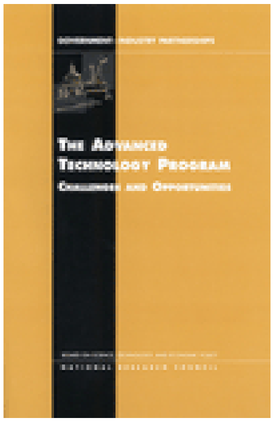

Advanced Technology Program: Challenges and Opportunities

Charles W. Wessner, Editor; Board on Science, Technology and Economic Policy, National Research Council

ISBN: 0-309-51434-7, 140 pages, 6 x 9, (1999)

This free PDF was downloaded from:
http://www.nap.edu/catalog/9699.html

Visit the National Academies Press online, the authoritative source for all books from the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and the National Research Council:

- Download hundreds of free books in PDF
- Read thousands of books online for free
- Purchase printed books and PDF files
- Explore our innovative research tools – try the Research Dashboard now
- Sign up to be notified when new books are published

Thank you for downloading this free PDF. If you have comments, questions or want more information about the books published by the National Academies Press, you may contact our customer service department toll-free at 888-624-8373, visit us online, or send an email to comments@nap.edu.

This book plus thousands more are available at www.nap.edu.

Copyright © National Academy of Sciences. All rights reserved.
Unless otherwise indicated, all materials in this PDF file are copyrighted by the National Academy of Sciences. Distribution or copying is strictly prohibited without permission of the National Academies Press <http://www.nap.edu/permissions/>. Permission is granted for this material to be posted on a secure password-protected Web site. The content may not be posted on a public Web site.

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

The Advanced Technology Program:
CHALLENGES AND OPPORTUNITIES

CHARLES W. WESSNER, *Editor*

NATIONAL ACADEMY PRESS
Washington, D.C.

NATIONAL ACADEMY PRESS • 2101 Constitution Ave., N.W. • Washington, D.C. 20418

The National Academy of Sciences is a private, nonprofit society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by Congress in 1863, the Academy has a mandate that requires it to advise the federal government on science and technical matters. Dr. Bruce Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

Limited copies are available from:
Board on Science, Technology,
and Economic Policy
National Research Council
1055 Thomas Jefferson, N.W.
Washington, D.C. 20007
202-334-2200

Additional copies are available for sale from:
National Academy Press
Box 285
2101 Constitution Ave., N.W.
Washington, D.C. 20055
800-624-6242
202-334-3313 (in the Washington Metropolitan Area)

International Standard Book Number 0-309-06775-8

Printed in the United States of America

For the National Research Council, this project was overseen by the Board on Science, Technology and Economic Policy (STEP), a standing board of the NRC established by the National Academies of Sciences and Engineering and the Institute of Medicine in 1991. The mandate of the STEP Board is to integrate understanding of scientific, technological, and economic elements in the formulation of national policies to promote the economic well-being of the United States. A distinctive characteristic of STEP's approach is its frequent interactions with public and private sector decisionmakers. STEP bridges the disciplines of business management, engineering, economics, and the social sciences to bring diverse expertise to bear on pressing public policy questions. The members of the STEP Board* and the NRC staff are listed below:

Dale Jorgenson, *Chair*
Frederic Eaton Abbe
Professor of Economics
Harvard University
Cambridge, Massachusetts

M. Kathy Behrens
Managing Partner
BancBoston Robertson Stephens
San Francisco, California

James F. Gibbons
Professor of Engineering
Stanford University
Stanford, California

Bronwyn H. Hall
Associate Professor of Economics
University of California
Berkeley, California

Ralph Landau
Consulting Professor of Economics
Stanford University
Stanford, California

Richard Levin
President
Yale University
New Haven, Connecticut

William J. Spencer, *Vice-Chair*
Chairman
SEMATECH
Austin, Texas

Mark B. Myers
Senior Vice President
Xerox Corporation
Stamford, Connecticut

Edward E. Penhoet
Dean, School of Public Health
University of California at Berkeley
Berkeley, California

A. Michael Spence
Dean, Graduate School of Business
Stanford University
Stanford, California

Joseph E. Stiglitz
Senior Vice-President for Development Economics
The World Bank
Washington, D.C.

Alan Wm. Wolff
Managing Partner
Dewey Ballantine
Washington, D.C.

---

*As of September 1999

Staff

Stephen A. Merrill
Executive Director

Charles W. Wessner
Program Director

John B. Horrigan
Staff Officer

Craig M. Schultz
Program Associate

Laura T. Holliday
Program Associate

McAlister T. Clabaugh
Program Associate

NATIONAL RESEARCH COUNCIL
BOARD ON SCIENCE, TECHNOLOGY, AND ECONOMIC POLICY

Sponsors

The National Research Council gratefully acknowledges
the support of the following sponsors:

U.S. Department of Defense

U.S. Department of Energy

National Cancer Institute

National Institute of Standards and Technology

National Aeronautics and Space Administration

National Science Foundation

Sandia National Laboratories

Electric Power Research Institute

Kulicke and Soffa Industries

Merck and Company

Milliken Industries

Motorola

Nortel

Procter and Gamble

Silicon Valley Group Incorporated

Advanced Micro Devices

STEERING COMMITTEE FOR GOVERNMENT-INDUSTRY PARTNERSHIPS FOR THE DEVELOPMENT OF NEW TECHNOLOGIES

Gordon Moore, *Chair*
Chairman Emeritus
Intel Corporation

M. Kathy Behrens
Managing Partner
BancBoston Robertson Stephens
and STEP Board

Gordon Binder
Chief Executive Officer
Amgen, Inc.

Michael Borrus
Co-Director
Berkeley Roundtable on International Economics

Iain Cockburn
Professor of Commerce and Business Administration
University of British Columbia

Kenneth Flamm
Dean Rusk Chair in International Affairs
LBJ School of Public Affairs
University of Texas at Austin

James F. Gibbons
Professor of Engineering
Stanford University
and STEP Board

William J. Spencer, *Vice-Chair*
Chairman, SEMATECH
and STEP Board

W. Clark McFadden
Partner
Dewey Ballantine

Mark B. Myers
Senior Vice President
Xerox Corporation
and STEP Board

Richard Nelson
George Blumenthal Professor of International and Public Affairs
Columbia University

Charles Trimble
Vice Chairman
Trimble Navigation

John P. Walker
Chairman and Chief Executive Officer
Axys Pharmaceuticals, Inc.

Patrick Windham
Lecturer
Stanford University
Consultant
Science and Technology Policy

Project Staff

Charles W. Wessner
Study Director

John B. Horrigan
Staff Officer

McAlister T. Clabaugh
Program Associate

Laura T. Holliday
Program Associate

Contents

III. PROCEEDINGS

Preface

The appropriate role of the government in the economy has been a source of controversy in the United States from its very origins. Perhaps the earliest articulation of the government's nurturing role with regard to the composition of the economy was Alexander Hamilton's 1791 *Report on Manufactures* in which he urged an activist approach by the federal government. At the time, Hamilton's views were controversial, although subsequent U.S. policy has largely reflected his beliefs.

Driven both by the exigencies of national defense and the requirements of transportation and communication across the American continent, the federal government has played an instrumental role in the development of new production techniques and technologies. In the early years of the republic, the federal government laid the foundation for the first machine tool industry with a contract for interchangeable musket parts.[1] A few decades later, in 1842, a hesitant Congress appropriated funds to demonstrate the feasibility of Samuel Morse's telegraph.[2]

---

[1] The 1798 contract with Eli Whitney is an early example of high technology procurement. Whitney missed his first delivery date and encountered what we now call substantial cost overruns. However, his invention of interchangeable parts, and the machine tools to make them, was ultimately successful. The muskets were delivered and the foundation of a new industry was in place. As early as the 1850s, the United States had begun to export specialized machine tools to the Enfield Arsenal in Great Britain. The British described the large-scale production of firearms, made with interchangeable parts, as "the American system of manufacturers" (David C. Mowery and Nathan Rosenberg, *Paths of Innovation: Technological Change in 20th Century America.* Cambridge University Press, New York, 1998, p 6).

[2] For a discussion of Samuel Morse's 1837 application for a grant and the congressional debate, see Irwin Lebow, *Information Highways and Byways: From the Telegraph to the 21st Century*. Institute

During both the nineteenth and twentieth centuries, the federal government has had an enormous impact on the structure and composition of the economy through infrastructure development, regulation, procurement, and a vast array of policies to support industrial and agricultural development.[3] Between World War I and World War II, these policies included support for the development of key industries, which we would now call dual-use, such as radios and aircraft frames and engines. The requirements of World War II generated a huge increase in government procurement and support for high-technology industries. At the industrial level, there were "major collaborative initiatives in pharmaceutical manufacturing, petrochemicals, synthetic rubber, and atomic weapons."[4] An impressive array of weapons based on new technologies was developed during the war, ranging from radar and improved aircraft, to missiles and, not least, the atomic bomb. Following the war, the federal government began to fund basic research at universities on a significant scale, first through the Office of Naval Research and later through the National Science Foundation.[5]

During the Cold War, the United States continued to emphasize technological superiority as a means of ensuring U.S. security. Government funds and cost-plus contracts helped to support systems and enabling technologies such as semiconductors and new materials, radar, jet engines, computer hardware and software, and missiles. For example, the government played a central role in the creation of the first electronic digital computer, the ENIAC.[6] In the post-Cold War period, the evolution of the American economy continues to be profoundly marked by government-funded research in areas such as microelectronics,

---

of Electrical and Electronics Engineers, New York, 1995, pp. 9-12. For a more detailed account, see Robert Luther Thompson, *Wiring a Continent: The History of the Telegraph Industry in the United States 1823-1836.* Princeton University Press, Princeton, N.J., 1947.

[3] Examples abound. The government played a key role in the development of the U.S. railway network, growth of agriculture through the Morrill Act (1862) and the agricultural extension service, and support of industry through the National Bureau of Standards (1901). See Richard Bingham, *Industrial Policy American Style: From Hamilton to HDTV.* New York: M.E. Sharpe, 1998 for a comprehensive review.

[4] David Mowery, "Collaborative R&D: How Effective Is It?" *Issues in Science and Technology.* 1998, p. 37.

[5] The National Science Foundation was initially seen as the agency that would fund basic scientific research at universities after World War II. However, disagreements over the degree of Executive Branch control over the NSF delayed passage of its authorizing legislation until 1950, even though the concept for the agency was first put forth in 1945 in Vannevar Bush's report *Science: The Endless Frontier*. The Office of Naval Research bridged the gap in basic research funding during these years. For an account of the politics of the NSF's creation, see G. Pascal Zachary, *Endless Frontier: Vannevar Bush, Engineer of the American Century*, New York: The Free Press, 1997, pp. 231. See also Daniel Lee Kleinman, *Politics on the Endless Frontier: Postwar Research Policy in the United States*, Durham, NC: Duke University Press, 1995.

[6] Kenneth Flamm, *Creating the Computer*. Washington, DC: The Brookings Institution, 1988, chapters 1-3. For a detailed account of ENIAC's creation see Scott McCartney, *ENIAC: The Triumphs and Tragedies of the World's First Computer*. New York: Walker and Company, 1999.

robotics, biotechnology, the human genome, and through investments in communications networks such as ARPANET—the forerunner of today's Internet.

Despite the important role the U.S. government has played in the development of the American economy, there is little consensus concerning the principle of government participation, although this may in part reflect limited knowledge about past and current government efforts to foster new technologies. There is also considerable debate about the appropriate mechanisms of participation. At the same time, in light of rising costs, substantial risks and the breadth of potential applications of new technologies, some believe that a supportive government policy framework is needed if new, welfare-enhancing and wealth-generating technologies are to be developed and brought to the market.

Since 1991 the National Research Council's Board on Science, Technology, and Economic Policy (STEP) has undertaken a program of activities to improve policy makers' understanding of the interconnections of science, technology, and economic policy and their importance for the American economy and its international competitive position. The Board's activities have corresponded with increased policy recognition of the importance of technology to economic growth. The new economic growth theory emphasizes the role of technology creation, which is believed to be characterized by significant growth externalities.[7] A consequence of the renewed appreciation of growth externalities is recognition of the economic geography of economic development. With growth externalities coming about in part from the exchanges of knowledge among innovators, certain regions become centers for particular types of high growth activities.[8]

In addition, some economists have suggested limitations to traditional trade theory, particularly with respect to the reality of imperfect international competition.[9] Recent economic analysis suggests that high-technology is often characterized by increasing rather than decreasing returns, justifying to some the proposition that governments can capture permanent advantage in key industries by providing relatively small, but potentially decisive support to bring national industries up the learning curve and down the cost curve. In part, this is why the economic literature now recognizes the relationship between technology policy and trade policy.[10] Recognition of these linkages and the corresponding ability

---

[7] Paul Romer, "Endogenous technological change," *Journal of Political Economy,* Vol. 98, 1990, p. 71-102. See also Gene Grossman and Elhanan Helpman, *Innovation and Growth in the Global Economy,* Cambridge, Mass., MIT Press, 1993.

[8] Paul Krugman, *Geography and Trade,* Cambridge, Mass., MIT Press, 1991, p . 23, points out how the British economist Alfred Marshall initially observed in his classic *Principles of Economics* how geographic clusters of specific economic activities arose from the exchange of "tacit" knowledge among business people.

[9] Paul Krugman, *Rethinking International Trade*, Cambridge, Mass., MIT Press, 1990.

[10] See J.A. Brander and B. J. Spencer "International R&D Rivalry and Industrial Strategy," *Review of Economic Studies,* vol. 50, 1983, pp. 707-722, and "Export Subsidies and International Market Share Rivalry," *Journal of International Economics*, vol. 16, 1985, pp. 83-100. See also A.K. Dixit

of governments to shift comparative advantage in favor of the national economy provides intellectual underpinning for government support for high-technology industry.[11] Another widely recognized rationale for government support for high technology exists in cases where technology generates benefits beyond those which can be captured by innovating firms, often referred to as spillovers.[12] There are also cases where the cost of given technology may be prohibitive for individual companies, even though expected benefits to society are substantial and widespread.[13]

PROJECT ORIGINS

The growth in government programs to support high technology industry within national economies and their impact on international science and technology cooperation and on the multilateral trading system are of considerable interest worldwide. Accordingly, these topics were taken up by STEP in a study carried out in conjunction with the Hamburg Institute for Economic Research and the Institute for World Economics in Kiel. One of the principal recommendations for further work emerging from that study was a call for an analysis of the principles of effective cooperation in technology development, to include lessons from national and international consortia, including eligibility standards and assessments of what new cooperative mechanisms might be developed to meet the challenges of international cooperation in high-technology products.[14]

In many high-technology industries, the burgeoning development costs for new technologies, the dispersal of technological expertise, the growing importance of regulatory standards, and environmental issues have provided

---

and A.S. Kyle, “The Use of Protection and Subsidies for Entry Promotion and Deterence,” *American Economic Review,* vol. 75, 1985, pp. 139-152, and P. Krugman and M. Obstfeldt, *International Economics: Theory and Policy.* 3rd Edition. New York, 1994.

[11] For a discussion of governments’ efforts to capture new technologies and the industries they spawn for their national economies, see National Research Council, *Conflict and Cooperation in National Competition for High-Technology Industry,* Washington, D.C., National Academy Press, 1996, p. 28-40. For a critique of these efforts see P. Krugman, *Peddling Prosperity.* W.W. Norton Press, New York, New York, 1994.

[12] See, for example, Martin N. Baily, and A. Chakrabarti, *Innovation and the Productivity Crisis.* The Brookings Institution, Washington, D.C., 1998, and Zvi Griliches, *The Search for R&D Spillovers.* Harvard University, Cambridge, Mass., 1990.

[13] See Ishaq Nadiri, *Innovations and Technological Spillovers.* NBER Working Paper No. 4423, 1993, and Edwin Mansfield, “Academic Research and Industrial Innovation,” *Research Policy,* February, 1991. Council of Economic Advisers, *Supporting Research and Development to Promote Economic Growth: The Federal Government’s Role.* Washington, D.C., 1995.

[14] The summary report of the project (*Conflict and Cooperation, op.cit.*) recommends further analytical work concerning principles for effective cooperation in technology development (see Recommendation 24, p. 8). More recently, David Mowery has noted the rapid expansion of collaborative activities and emphasized the need for comprehensive assessment. David Mowery, “Collaborative R&D: how effective is it?” *op. cit.,* p. 44.

powerful incentives for public-private cooperation. Notwithstanding the unsettled policy environment in Washington, collaborative programs have expanded substantially with perhaps as many as seventy federal cooperative technology programs currently underway.[15] Under the Reagan administration, after much debate, SEMATECH was established to address the competitive challenge facing the semiconductor industry.[16] During the Bush administration, Congress first funded the Advanced Technology Program (ATP) in the National Institute of Standards and Technology (NIST) and the Advanced Battery Consortium was created. The Clinton administration came to office with an emphasis on civilian technology programs, substantially expanding the ATP and creating the Technology Reinvestment Program (TRP).[17] The rapid expansion of some programs encountered significant opposition, rekindling the national debate on the appropriate role of the government in fostering new technologies. Indeed, broader philosophical questions about the appropriate role for government in collaborating with industry have tended to obscure the need for policy makers to draw lessons from current and previous collaborative efforts.

Given the considerable change in federal research and development budgets since the end of the Cold War, and the reduced role of many centralized laboratories in the private sector, government-industry collaboration is of growing importance, yet it has seen remarkably little objective analysis. At one level, analysis may contribute to a better appreciation of the role of collaboration between government and industry in the development of the U.S. economy. Writing twenty years ago, one well-known American economist observed that Americans are still remarkably uninformed about the long history of policies aimed at stimulating innovation.[18] Today, many Americans seem to appreciate the contribution

---

[15] Dan Berglund and Christopher Coburn, *Partnerships: A Compendium of State and Federal Cooperative Technology Programs.* Battelle Press, Columbus, 1995, p. 481.

[16] The Semiconductor Industry Association formally proposed the SEMATECH consortium in May 1997. For an overview of SEMATECH's operation and contribution, see *Conflict and Cooperation*, 1996, *op.cit.,* pp. 141-151. For one of the most comprehensive assessments of SEMATECH, see John B. Horrigan, "Cooperating Competitors: A Comparison of MCC and SEMATECH," monograph, National Research Council, Washington, D.C. forthcoming.

[17] For an overview of the ATP, see Christopher T. Hill, "The Advanced Technology Program: opportunities for enhancement," in Lewis Branscomb and James Keller, eds. *Investing in Innovation: Creating a Research and Innovation Policy.* Cambridge, Mass., MIT Press, 1998, pp. 143-173. For an excellent analysis of the TRP, see Jay Stowsky, "Politics and Policy: The Technology Reinvestment Program and the Dilemmas of Dual Use." Mimeo, University of California, 1996. See *Effectiveness of the United States Advanced Battery Consortium as a Government-Industry Partnership,* National Academy Press, Washington, D.C., 1998.

[18] Otis L. Graham, *Losing Time: The Industrial Policy Debate.* Harvard University Press, Cambridge, Mass., 1992, p. 250. Graham cites Richard Nelson's observations at the end of the Carter Administration. The situation may not have improved. Writing in 1994, James Fallows makes a similar observation (see *Looking into the Sun*: *The Rise of the New East Asian Economic and Political System.* New York: Pantheon Books, 1994, p. 196). See also Thomas McCraw's "Mercantilism and the market: antecedents of American industrial policy," in *The Politics of Industrial Policy,* Claude E.

of new technologies to the current, robust economic growth. Yet there is little evidence that Americans are aware of the contributions of federal support for technological innovation, from radio to computers to the Internet.[19]

In addition to a better understanding of how the U.S. economy developed and the supportive role the government played in its development, careful assessment of support for new technologies can be called for because government intervention in the market can be fraught with risk. There are cases of major success resulting from federal support to the computer or semiconductor industries, where the Department of Defense served as a source of R&D and as a reliable, early buyer of products and later through its support for SEMATECH.[20,21] There are also cases of major frustration. Landmarks would include projects such as the Supersonic Transport and the Synfuels Corporation.[22] Regular assessment is vital to ensure continued technical viability, though cost-sharing requirements can be an effective safeguard. Assessment can also help avoid "political capture" of projects, especially large commercial demonstration efforts.[23] Even successful collaborations face the challenge of adapting programs to rapidly changing technologies.[24] Assessment thus becomes a means of keeping programs relevant. Assessment can also have the virtue of reminding policymakers of the need for humility before the "black box" of innovation. As one observer notes,

---

Barfield and William A. Schambra, eds., American Enterprise Institute for Public Policy Research, Washington, D.C., 1986, pp. 33-62.

[19] For an excellent review of government support for computers and the internet, see National Research Council, *Funding A Revolution: Government Support for Computing Research.* National Academy Press, Washington D.C., 1999, pp. 85-135 and pp. 169-183.

[20] Graham, *op. cit*., p. 2.

[21] Market opening measures, such as the Semiconductor Trade Agreement (SCTA), also played an important role in preventing dumping and improving market access for U.S. firms. For a review of the SCTA see *Conflict and Cooperation,* p. 81, note 211, and pp. 131-141. See also Kenneth Flamm, *Mismanaged Trade? Strategic Policy and the Semiconductor Industry.* The Brookings Institution, Washington, D.C., 1996.

[22] See Linda R. Cohen and Roger G. Noll, *The Technology Pork Barrel*, The Brookings Institution, Washington, D.C., 1991, pp. 97, 178, 259-320, 217-258. An interesting review of technology development programs, mainly from the 1970s, the analysis is less negative than the title suggests. Indeed, the volume identifies some successful R&D projects such as the photovoltaic electricity program.

[23] Cohen and Noll stress that political capture by distributive congressional politics and industrial interests are one of the principal risks for government-supported commercialization projects. In cases such as the Supersonic Transport project, they extensively document the disconnect between declining technical feasibility and increasing political support, see Cohen and Noll, *op.cit.,* p. VII and pp. 242-257.

[24] One of the strengths of SEMATECH was its ability to redefine goals in the face of changing conditions. See *Conflict and Cooperation*, 1996*, op.cit.,* p. 148. See also Grindley, et. al., "SEMATECH and collaborative research: lessons in the design of high-technology consortia." *Journal of Policy Analysis and Management,* 1994, p. 724.

"experience argues for hedged commitments, constant reappraisal, maintenance of options, and pluralism of advice and decision makers."[25]

From an international perspective, understanding the benefits and challenges of these programs is also important insofar as they have been, and remain, a central element in the national development strategies of both industrial and industrializing countries. Governments have shown a great deal of imagination in their choice of mechanisms designed to support industry. They have adopted a wide range of policies from trade regulations designed to protect domestic products from foreign competition, to tax rebates intended to stimulate the export of selected domestic products. They provide government R&D funding for enterprises of particular interest, and sometimes give overt support through direct grants, loans, and equity investments or more opaque support through mechanisms such as tax deferral.[26] Data collected by the Paris-based Organization for Economic Cooperation and Development suggest that worldwide government expenditures on support for high-technology industries involve significant resources and are increasingly focused on what policy makers consider to be strategic industries.[27]

The United States is an active, if unavowed, participant in this global competition, at both the state and the federal level. Indeed, the United States has a remarkably wide range of public-private partnerships in high-technology sectors.[28] In addition to the well-known cases mentioned above, there are public-private consortia of many types. They can be classified in a number of ways, such as by the economic objective of the partnership, that is, to leverage the social benefits associated with federal R&D activity, to enhance the position of a national industry, or to deploy industrial R&D to meet military or other government missions.[29] An illustrative list would include partnerships in sectors such as electronic storage, flat panel displays, turbine technologies, new textile manufacturing techniques, new materials, magnetic storage, next-generation vehicles, batteries, biotechnology, optoelectronics, and ship construction. The list would also include programs such as the national manufacturing initiative, the National

---

[25] Otis Graham, op.cit., p. 251. Graham is referring to work by Richard R. Nelson in *Government and Technological Progress*, Pergamon Press, New York, 1982, p. 454-455.

[26] For an overview of the policy goals and instruments, see *Conflict and Cooperation*, *op.cit.,* Box B., pp. 39-40. See also Martin Brown, *Impacts of National Technology Programs.* OECD, 1995, especially chapter two.

[27] *Ibid.*

[28] See Chris Coburn and Dan Bergland, *Partnerships*. Batelle Press, Columbus, Ohio, 1995.

[29] See Albert Link, "Public/Private Partnerships as a Tool to Support Industrial R&D: Experiences in the United States." Paper prepared for the working group on Innovation and Technology Policy of the OECD Committee for Science and Technology Policy, Paris, 1998, p. 20. Partnerships can also be differentiated by the nature of public support. Some partnerships involve a direct transfer of funds to an industry consortium. Others focus on the shared use of infrastructure, such as laboratory facilities.

Science Foundation's (NSF) engineering research centers, NSF's science and technology centers, NIST's Manufacturing Extension Program, and the multiagency Small Business Innovation Research Program, among others. University-industry cooperation is also on the upswing, with a significant percentage of university R&D now supported by industry and through innovative cooperation efforts such as Semiconductor Industry Association's MARCO program. In addition, there are extensive cooperative agreements with the national laboratories. The proliferation of these programs provides a rich base of experience for assessment.

PROJECT STEERING COMMITTEE

The expansion of cooperative activities highlights the need for better understanding of the opportunities and limitations of these programs and the conditions most likely to ensure success. Reflecting the interest of policy makers in this topic, the STEP Board initiated the project on "Government-Industry Partnerships for the Development of New Technologies," which has benefited from broad support among federal agencies. These include the U.S. Department of Defense, the U.S. Department of Energy, the National Science Foundation, the National Institutes of Health, the National Aeronautics and Space Administration, the National Institute of Standards and Technology, the Sandia National Laboratories, and the Electric Power Research Institute, as well as a diverse group of private corporations (listed in the front matter). To carry out this analysis, the STEP Board has assembled a distinguished multidisciplinary steering committee for this assessment of government-industry partnerships, chaired by Gordon Moore, the Chairman Emeritus of Intel (the Committee is also listed in the front matter). The committee's principal tasks are to provide overall direction and relevant expertise in the assessment of the issues raised by the project. At the conclusion of the project, the steering committee will develop a consensus report outlining their findings and recommendations on the issues reviewed by the project.

As a basis for the consensus report, the steering committee has undertaken to commission research and convene a series of fact-finding meetings in the form of workshops, symposia, and conferences as a means of informing its deliberations. The symposium on the Advanced Technology Program (ATP) represents one element of this fact finding effort. It is the fourth in a series of fact-finding meetings convened under the auspices of the STEP Board and under the direction of the steering committee.[30]

---

[30] Current and forthcoming publications of the Government-Industry Partnerships Project include:

The SBIR Program: Challenges and Opportunities. National Academy Press, Washington, D.C., 1999.

New Vistas in Transatlantic Science and Technology Cooperation. National Academy Press, Washington D.C., 1999.

A number of distinguished individuals deserve recognition for their willingness to review this report. These individuals were chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review process: Dr. Robert Archibald, The College of William and Mary; Dr. David Audretsch, Indiana University; Robert H. Wilson, University of Texas at Austin, Dr. Albert Link, University of North Carolina, Greensboro; Dr. John Scott, Dartmouth University; Dr. Mary Good, Venture Capital Investors; and Dr. Maryann Feldman, Johns Hopkins University. We are especially grateful for the contributions of the report coordinator, Dr. France Córdova. The reviewers have provided constructive comments and suggestions; however, it must be emphasized that responsibility for the final content of this report rests entirely with the Board on Science, Technology, and Economic Policy and the National Research Council. We would also like to thank the many members of the NIST staff who generously contributed their time and expertise. Recognition is also due to the STEP staff responsible for the preparation of the conference and the report. Dr. John Horrigan deserves special recognition for his instrumental role in preparing the report and for his many substantive contributions to the introduction. Similarly, Laura Holliday, and more recently, McAlister Clabaugh, provided invaluable assistance in the organization of the meeting and the preparation of this report. Their interest, commitment, and willingness to work long hours enabled us to accommodate NIST's January request to organize a conference and prepare a summary report by September amidst the other activities of the Government-Industry Partnerships Project.

Given the quality and number of presentations at this second symposium, summarizing the proceedings was a challenge. Every effort was made to capture the main points made during presentations and ensuing discussions, within the constraints imposed by the nature of a symposium summary. We apologize in advance for inadvertent errors and omissions in the summary. We also take this opportunity to thank our speakers and participants for making their experience and expertise available to the Advanced Technology Program and the Academies analysis of the program. Finally, we emphasize that the proceedings that follow do not include formal findings or recommendations of the Academies. The

---

A Review of the Sandia Science and Technology Park Initiative. National Academy Press, Washington D.C., 1999.

The Small Business Innovation Research Program: An Assessment of DoD's Fast Track Initiative. National Academy Press, Washington D.C., forthcoming.

objective of this volume is to capture the different perspectives of the participants on the objectives, operations, and assessment of the Advanced Technology Program and thereby contribute to a better understanding of the program and the role of government and industry in bringing new technologies to the marketplace.

Charles W. Wessner

Introduction

The 1970s and the 1980s was a time of economic change and uncertainty in the United States—a period marked by slow economic growth relative to post-war norms, sluggish productivity performance, and a rapidly rising trade deficit. The causes of America's sub-par economic performance defied definitive analysis, but dire warnings of U.S. economic decline and the "deindustrialization" of key manufacturing sectors proliferated.[1] Looming large in the debate was the loss in competitive position of key U.S. industries, from steel and automobiles to televisions and semiconductors. U.S. trade competitors, such as Japan, seemed to have arrived at an economic model different in important respects from the traditional laissez-faire American approach.[2] A key feature of that model was its emphasis on cooperation rather than competition. The ability of different arms of Japanese industry to work with one another, and the close relationship between government and industry in supporting key economic sectors had created substantial benefits for the Japanese economy.[3]

---

[1] Questions persist concerning the degree of the U.S. decline in the 1980s, just as questions remain concerning the sustainability of the current recovery. The STEP Board has recently completed a review of the competitive resurgence of the U.S. economy. It includes an assessment of the factors which have contributed to the U.S. recovery with a focus on eleven U.S. manufacturing and service sectors. See: Mowery, D. ed. (1999) *U.S. Industry in 2000: Studies in Competitive Performance.* Washington, D.C.: National Academy Press.

[2] For review of these issues see *Conflict and Cooperation*, op. cit. pp. 12-40. For a review of the main features of the East Asian economic success story, see *The East Asian Economic Miracle: Economic Growth and Public Policy,* World Bank Policy Research Report, Oxford University Press, New York, 1993.

[3] For the best early analysis of the Japanese approach, see Chalmers Johnson, *MITI and the Japa-*

One of the strategies adopted by the United States in response to its loss in competitiveness (at least in some sectors) was to encourage greater cooperation among industry and between industry and government. Such collaboration was by no means novel in the U.S. economy. Government funds had supported the demonstration and development of the telegraph in the last century, and after World War I, the federal government fostered an independent radio industry.[4] As noted in the preface, the federal government also provided active support through a variety of mechanisms for military and civil aviation and the electronics industry.[5] Yet the 1980s and early 1990s saw a conscious effort to expand cooperation, in part by using federal R&D funding more effectively, to meet what were seen as unprecedented competitive challenges.

A series of public and private initiatives in the 1980s demonstrate the renewed emphasis on cooperation. The change in public policy is illustrated by the number of major legislative initiatives passed by the Congress. These included: the Stevenson-Wydler Technology Innovation Act (1980), the Bayh-Dole University and Small Business Patent Act (1980), the Small Business Innovation Development Act (1982), the Federal Technology Transfer Act (1986), the Omnibus Trade and Competitiveness Act (1988), the National Competitiveness Technology Transfer Act (1989), and the Defense Conversion, Reinvestment, and Transition Assistance Act (1992). These individual acts are summarized in the box on the following page.

---

nese Miracle: The Growth of Industrial Policy 1925-1975. Stanford University Press, Stanford, California, 1982. D.T. Okimoto, "The Japanese Challenge in High Technology Industry," in R. Landau and N. Rosenberg, eds., *The Positive Sum Strategy*. National Academy Press, Washington, D.C., 1986, and, by the same author, *MITI and the Market: Japanese Industrial Policy for High Technology Industry.* Stanford University Press, Stanford, California, 1989.

[4] Josephus Daniels, Secretary of the Navy during the Wilson administration, appeared to feel that monopoly was inherent to the wireless industry, and if that were the case, he believed the monopoly should be American rather than British. Britain had dominated pre-war Atlantic wireless traffic as well as the undersea telegraph cable. With Navy sponsorship and participation, the patents of General Electric, AT&T, Westinghouse, and the Navy were pooled in order to create the Radio Corporation of America. See Irwin Lebow, *Information Highways and Byways: op. cit.*, pp. 97-98 and chapter 12.

[5] David C. Mowery and Nathan Rosenberg, *Technology and the Pursuit of Economic Growth.* Cambridge University Press, Cambridge England, 1989. See chapter seven especially pp. 181-194. The authors note that the commercial aircraft industry is unique among manufacturing industries in that a federal research organization, the National Advisory Committee on Aeronautics (founded in 1915 and absorbed by NASA in 1958) conducted and funded research on airframe and propulsion technologies. Before World War II, NACA operated primarily as a test center for civilian and military users. NACA made a series of remarkable contributions with regard to engine nacelle locations and the NACA "cowl" for radial air cooled engines. These innovations, together with improvements in engine fillets based on discoveries at Caltech and the development of monocoque construction, had a revolutionary effect on commercial and military aviation. These inventions made the long-range bomber possible, forced the development of high-speed fighter aircraft, and vastly increased the appeal of commercial aviation. Ibid. and personal communication with Albert Flax, National Academy of Engineering.

Principal Federal Legislation Related to Cooperative Technology Programs[6]

- **Stevenson-Wydler Technology Innovation Act (1980)** Required federal laboratories to facilitate the transfer of federally owned and originated technology to state and local governments and the private sector. The Act includes a requirement that each federal lab spend a specified percentage of its research and development budget on transfer activities and that an Office of Research and Technology Applications (ORTA) be established to facilitate such transfer.
- **Bayh-Dole University and Small Business Patent Act (1980)** Permitted government grantees and contractors to retain title to federally funded inventions and encouraged universities to license inventions to industry. The Act is designed to foster interaction between academia and the business community. This law provided, in part, for title to inventions made by contractors receiving federal R&D funds to be vested in the contractor if they are small businesses, universities, or not-for-profit institutions.
- **Small Business Innovation Development Act (1982)** Established the Small Business Innovation Research (SBIR) Program within the major federal R&D agencies to increase government funding of research with commercialization potential in the small high-technology company sector. Each federal agency with an R&D budget of $100 million or more is required to set aside a certain percentage of that amount to finance the SBIR effort.
- **National Cooperative Research Act (1984)** The National Cooperative Research Act of 1984 eased antitrust penalties on cooperative research by instituting single, as opposed to treble, damages for antitrust violations in joint research. The Act also mandated a "rule of reason" standard for assessing potential antitrust violations for cooperative research. This contrasted with the *per se* standard by which any R&D collusion is an automatic violation, regardless of a determination of economic damage.
- **Federal Technology Transfer Act (1986)** Amended the Stevenson-Wydler Technology Innovation Act to authorize cooperative research and development agreements (CRADAS) between federal laboratories and other entities, including state agencies.
- **Omnibus Trade and Competitiveness Act (1988)** In addition to establishing the Competitiveness Policy Council, designed to enhance U.S. industrial competitiveness, the Act created several new programs

---

[6] Drawn, with NRC modifications, from Berglund and Coburn, *op.cit.,* p. 485.

(e.g., the Advanced Technology Program and the Manufacturing Technology Centers) housed in the Department of Commerce's National Institute of Standards and Technology and intended to help commercialize promising new technologies and to improve manufacturing techniques of small and medium-sized manufacturers.

- **National Competitiveness Technology Transfer Act (1989)** Part of the Department of Defense authorization bill, this act amended the Stevenson-Wydler Act to allow government-owned, contractor-operated laboratories to enter into cooperative R&D agreements.
- **Defense Conversion, Reinvestment, and Transition Assistance Act (1992)** Initiated the Technology Reinvestment Project (TRP) to establish cooperative, interagency efforts that address the technology development, deployment, and education and training needs within both the commercial and defense communities.

Private sector cooperation was encouraged by the reduction in anti-trust concerns. In 1984, Congress overwhelmingly passed the National Cooperative Research Act, which eased antitrust penalties for companies conducting joint research and development. Responding to this new environment, the private sector also undertook a series of innovative approaches to address its competitive failings. For example, in 1983, fourteen companies—mostly computing manufacturers, but also semiconductor, aerospace, and defense firms—banded together to form the Microelectronics and Computer Technology Corporation (MCC), in part as a response to Japan's Fifth Generation Computer project.[7] In 1987, two parallel study efforts in the public and private sectors recommended the establishment of a consortium to improve manufacturing technology in the semiconductor industry, which had lost leadership in manufacturing and was losing market share to Japanese firms at a rapid rate. The result was SEMATECH, a $200 million per year consortium funded half by the government and half by the private sector.[8]

While perhaps one of the most successful, SEMATECH was by no means the only technology development program launched by the federal government. Some of the other major federal efforts of this type are: the Department of Defense's Manufacturing Technology (MANTECH) program; the now defunct Technology Reinvestment Project (TRP); the Department of Transportation's Intelligent Vehicle Highway Systems (IVHS) Program and National Magnetic Levitation Initiative (MAGLEV); the National Science Foundation's Research

---

[7] For a review of the origins of MCC and SEMATECH, see John Horrigan, *op. cit.*

[8] In 1996, SEMATECH became a completely private sector consortium.

Centers Program (which includes the Engineering Research Centers, the Industry/University Cooperative Research Centers, the Materials Research Science and Engineering Centers, and the Science and Technology Centers); and the Small Business Technology Transfer (STTR) program.[9]

The notion of additional government-industry collaboration was well-developed by the late 1980s, but by no means universally accepted. One of the earliest calls for increased collaboration, the President's Commission on Industrial Competitiveness, was released in 1983, but few of its recommendations were adopted.[10] The recommendations for expanded cooperation of a subsequent study effort, the National Advisory Committee on Semiconductors (NACS) also met with limited success though it served to highlight the importance of this strategic sector to the U.S. economy.[11] Even a broadly supported initiative such as SEMATECH, whose government funding in hindsight may have always seemed secure, encountered serious opposition at its inception.[12]

Another element in the economic and policy landscape at the time was the demise of the "spinoff" paradigm in defense procurement. For years it had been assumed, accurately or not, that investments in sophisticated defense systems had beneficial spillovers into commercial markets. Companies that developed and manufactured high-technology armaments were believed to be building a technological base that would enable them to compete effectively in commercial markets.[13] For a number of reasons—from burdensome government procurement regulations to accelerating time-to-market demands in commercial markets—this paradigm no longer applied by the 1980s.[14] In fact, it was increasingly recognized that only firms competitive in commercial markets were able to provide military systems with the most advanced capabilities, particularly in rapidly

---

[9] Berglund and Coburn, *op.cit.,* p. 488.

[10] See President's Commission on Industrial Competitiveness, *Global Competition: The New Reality.* Government Printing Office, Washington, D.C., 1985, 2 vols.

[11] See National Advisory Committee on Semiconductors, *Semiconductors: A Strategic Industry at Risk.* A Report to the President and the Congress, Semiconductor Industry Association, Washington, D.C., 1989. See also National Advisory Committee on Semiconductors, *Toward a National Strategy for Semiconductors.* Semiconductor Industry Association, Washington, D.C., 1991.

[12] The 1992 renewal was undertaken in the era in which the President's economic advisors purportedly saw little difference between silicon chips (semiconductors) and potato chips.

[13] In some cases, such as aircraft and computing in the early years, this assumption did hold. See David Mowery, *op.cit.,* p. 184-189, and *Funding a Revolution*, op.cit., passim.

[14] Some analysts argue that the U.S. defense acquisition system, far from being a guise for the support of commercially relevant industry, has in fact created disincentives and barriers to the operation of market forces. These include "the unique government oversight requirements, the unique procurement requirements, (and) the unique military specifications" associated with military procurement. See the presentations of Jacques Gansler in Charles Wessner, ed., *International Friction and Cooperation in High-Technology Development and Trade.* Washington, D.C.: National Academy Press, 1997.

evolving sectors such as semiconductors.[15] The Reagan administration also saw the creation of the Advanced Technology Program (ATP) in the National Institute of Standards and Technology. In addition to providing the initial funding for the ATP, the Bush administration cooperated with Congress in extending authority for Cooperative Research and Development Agreements (CRADAs) to some Department of Energy laboratories. This provided the legal framework which later permitted significant cooperative programs to be undertaken, such as AMTEX and the PNGV.[16] Policymakers were therefore searching for ways to assist private sector commercialization rates, not only because of competitiveness concerns, but for national security reasons as well.

It was in this environment of heightened concern about U.S. competitiveness and a desire to ensure the U.S. economy benefited from federal R&D investments that the Advanced Technology Program (ATP) was conceived. The legislation establishing ATP was part of the Omnibus Trade Act of 1988, a complex bill whose main objective was to provide policy instruments to address the rapidly growing U.S. trade deficit. The sponsors of the Advanced Technology Program initiative were Senator Ernest Hollings of South Carolina and Representative George Brown of California. The initial appropriation was small, only $10 million for 1990.

ATP was initiated as a means of funding high-risk R&D with broad commercial and societal benefits that would not be undertaken by a single company or group of companies, either because the risk was too high or because the benefits of success would not accrue to the investors. In this regard, the program lacked the straight forward security rationale that had usually underpinned post-war U.S. technology programs. It did, however, reflect a general trend away from purely mission-oriented research and development towards facilitating more broadly based technological advances. In particular, it was seen as a means of facilitating the economic growth that comes from the commercialization and use of new technologies in the private sector.

---

[15] In response to changing procurement needs, the Clinton Administration adopted a "dual use" strategy for defense procurement. See *Conflict and Cooperation*, op.cit., pp. 153-158. See also the presentations of Paul Kaminski and Jacques Gansler in *International Friction and Cooperation in High-Technology Development and Trade*, op. cit., pp. 130-152. For a discussion of the demise of the spinoff paradigm, see John Alic, et. al., *Beyond Spinoff: Military and Commercial Technologies in a Changing World*. Boston: Harvard Business School Press, 1992.

[16] AMTEX stands for the American Textile Partnership, a consortium of five industry research, education, and technology transfer organizations, and eight national laboratories. Established in 1993, the agreement is designed to bring the resources of the DOE laboratories to the American fibers, textiles, and fabricated products industry. Research objectives for the multi-million dollar research agreement include improved materials and processes; simulation and computer integration for demand-activated manufacturing; waste minimization and automation. James Burroughs, "AMTEX—An Exciting Vision of the Future, " *American Textiles International,* May 1993. PNGV is the Program for Next Generation Vehicles; for a review of this program see National Research Council, *Review of the Research Program of the Partnership for a New Generation of Vehicles: Third Report.* Washington, DC: National Academy Press, 1997.

Attached to a popular trade bill, the program was enacted into law, although without the enthusiastic support of the Reagan Administration. From its modest first year funding of $10 million, the program grew with the support of a Democratic Congress to nearly $68 million in the final year of the Bush Administration. As noted above, the Clinton Administration proposed and initially won substantial increases in ATP funding, but this high profile approach also generated significant opposition to the program.[17]

One consequence of the sometimes intense debate about government-industry partnerships in general and the ATP in particular, has been a desire for objective analysis of the goals, operation and results of partnership programs. As a 1995 study observed:

> The federal government has undergone a sea change the past few years in its approach to the private sector. The broad awareness of and support for these activities in Congress and their spread throughout the $80 billion federal R&D system ensure that they will continue well into the next Administration and beyond. The debate should address not whether these programs will endure, but whether they are shaped properly—at the program and aggregate levels—to achieve the desired benefits.[18]

To carry out such an analysis, the National Academies have undertaken a broad gauge study entitled "Government-Industry Partnerships for the Development of New Technologies." As described in the preface, this project is being carried out under the auspices of the Board on Science, Technology, and Economic Policy, and is intended to contribute to improved understanding of partnerships through a series of conferences and workshops bringing together policy makers, program managers, academic experts, technologists, and representatives of industry.

This volume, which is one in a series,[19] summarizes the deliberations of a symposium undertaken at the request of the leadership of the National Institute of Standards and Technology (NIST), the agency which administers the Advanced Technology Program. The one-day symposium, held on March 29, 1999, brought together economists, ATP officials, and representatives of private industry to

---

[17] As one observer put it, "the irony of White House leadership on this issue has been that what was once a nonpartisan issue in the Congress acquired a partisan undertone. Legislative objectives that received broad support in both parties as recently as the early 1990s can now be cause, at times, for heated debate on the role of the government." Berglund and Coburn, *op. cit.* p. 484.

[18] *Ibid.,* p. 487. The 1993 passage of the Government Performance and Results Act requires federal agencies to set strategic goals and to use performance measures for management and budgeting. This is particularly challenging for agencies responsible for research activities and makes the NIST evaluation effort, as well as this study of government-industry partnerships, particularly relevant. For a review of the issues in applying GPRA to federal research, see Evaluating Federal Research Programs: Research and the Government Performance and Results Act, National Academy Press: Washington, D.C., 1999.

[19] See Preface.

discuss ATP's rationale, program strengths and weaknesses, and consider areas for improvement. The NIST request itself was in response to a congressional mandate to provide an independent review of program operations. The text which follows provides an overview of the day's proceedings.

OVERVIEW

Measurement and the Advanced Technology Program

The symposium was fortunate to have Ray Kammer, Director of NIST, give opening remarks and contribute to the discussion during the entire day's proceedings. Mr. Kammer pointed out that measurement goes to the core of NIST's mission, so it should come as no surprise that NIST is greatly interested in measuring the outcomes of its programs, such as the ATP. ATP's mission—to promote the development of generic technologies that industry is unlikely to fund on its own, but which potentially have great payoffs to society—presents considerable measurement challenges. Government support in the early stage of a technology's development can enable society as a whole to reap great economic benefits. The Internet, springing from relatively modest investment from the Defense Department, the National Science Foundation, and universities, is a classic example.[20] Such *ex post* analysis is useful, he noted, but the political climate often demands an *ex ante* demonstration of when a given investment will pay off and to what extent. Given that ATP's mission is to invest in technologies with long-range, broad-based economic benefits, the measurement task for a program such as ATP is intrinsically challenging.

Nonetheless, measurement has been a part of the Advanced Technology Program since its beginning. The Economic Assessment Office has been an integral part of ATP since the program's inception and ATP's business reporting system closely tracks the progress of ATP awards. To date, ATP has funded 431 projects at a total of $1.39 billion; the private sector has essentially matched that amount, bringing total public/private expenditures on ATP projects to $2.78 billion. Many of these projects have multiple participants; over 1,000 organizations, 125 universities, and 20 national laboratories are involved in ATP projects. The assessment studies conducted for ATP have shown positive economic returns to these projects, most companies say that ATP grants have accelerated R&D cycles, and nearly two-fifths report that they would not have undertaken the research at all without the ATP grant. While quoting Commerce Secretary William Daley that recent ATP assessments present "a portrait of a program that works," Mr. Kammer said that an ongoing challenge "is to document how the ATP affects the economy, and by how much."

---

[20] For an excellent review of the early funding for the internet, see *Funding A Revolution, op.cit.*

History of ATP

The symposium's first panel discussed the ATP's history and current legislative outlook for the Advanced Technology Program. In setting the context for the panel, Dr. Christopher Hill of George Mason University placed ATP's development squarely within U.S. economic conditions of the 1980s, during which time the expansion of Japanese firms' share of high and medium technology markets (e.g. semiconductors and automobiles) seemed to pose a major competitive challenge to the United States. Technology policy usually receives the greatest attention during periods of economic distress; consequently, policy experiments to encourage cooperation received relatively sympathetic hearings during the 1980s, even if government support of industrial R&D was far from an alien concept before then. The politics of ATP were notable, said Dr. Hill, because congressional staff played a major role in the program's creation. The likely business beneficiaries were initially "oblivious, lukewarm, and indifferent" to the program.[21] In this situation, the program's attachment to the Omnibus Trade Bill was instrumental to its enactment.

The program did grow modestly during the Bush Administration, from $10 million to $68 million, and expanded rapidly under the Clinton Administration. The arrival of the Republican Congress in 1995 changed the political landscape, and the hostility of Robert Walker, then Chairman of the House Science Committee, seemed to threaten the program's existence. Perhaps reflecting these political realities, Dr. Hill noted that it is remarkable that the Clinton Administration, has not put forward major technology policy legislative initiatives.[22] Dr. Hill attributed this lacuna to the strong U.S. economy in the Clinton years. In his view, to the extent that government programs have contributed to this performance, past investments in programs such as the Defense Advanced Research Projects Agency deserve the credit.

The wide-ranging discussion following Dr. Hill's remarks focused on ATP's rationale, evaluation, and impact. Dr. Claude Barfield remarked that ATP is often talked about in terms of its benefits to specific companies, whereas the economic rationale for the program should concentrate on its social benefits—the externalities it creates that accrue to society. Evaluation of ATP, he said, should

---

[21] This is no longer the case. There is active support for the program from both large and small companies, notably through the industry-led Coalition for Techology Partnerships, and numerous professional societies.

[22] As Dr Hill notes, the mid-nineties were not a propitious time for new partnership initiatives. Elements of the new Congress advocated the elimination of entire departments, e.g. Commerce, and organizations, e.g. the Office of Technology Assessment (which was disbanded) as well as programs such as TRP and ATP. The budget deficit also contributed to a climate in which new partnership initiatives were difficult. The Clinton Administration did initiate the PNGV program and the Environmental Technology program. Recent initiatives include the expanded support for human genome research and information technology programs such as Next Generation Internet and IT^2.

focus on social benefits. From the Congressional staff perspective, James Turner and David Goldston both underscored the importance placed on evaluating the ATP from the program's inception.[22] As valuable as evaluation has been, Mr. Goldston noted its limits; policymakers often want to know the net economic benefits of a program such as ATP (sometimes even before committing funds), and evaluations of technology programs can rarely provide this information. Mr. Turner said that evaluation was built into the structure of the program when it was established, even though the inherent limits of evaluation were known. Mr. Turner emphasized that ATP was originally envisioned as a program with a limited scope—namely to address pre-competitive generic technologies—and that drafters of ATP legislation chose to make the program industry led, meaning companies had to bring money to the table to receive funding. Finally, Mr. Turner responded to Dr. Loren Yager's comments that had policymakers known in 1988 how the U.S. economy would regain its preeminence, they probably would not have created ATP. Notwithstanding the growing belief that America has a "New Economy" with unparalleled growth potential, Mr. Turner noted that the Japanese experience underscores how uncertain such economic predictions can be.[24] Programs such as ATP, which target high-risk technologies at modest levels of public funding, may be viewed as wise investments in the future.

Program Operations

Dr. Lura Powell, Director of the Advanced Technology Program, described the selection process that ATP proposals undergo. Industry submits proposals to ATP, and ATP undertakes a general review of a proposal to see whether it involves sufficient technical risk, is feasible, and promises the widespread economic benefits that ATP wishes to foster. Each proposal undergoes review by technical and business experts, such as retired industrialists and researchers. Because the criteria for awarding ATP grants require that technologies have significant risk and broad-based economic benefits, there is a low likelihood that ATP awards will replace private capital. Venture capitalists, said Dr. Powell, search for projects that will generate private benefits, whereas ATP, with the focus on pre-competitive technologies, seeks out projects whose economic benefits will be significant, but also have the potential to diffuse across a sector or the economy as a whole.

---

[23] In a recent article discussing the challenges facing the SBIR program, James Turner and the late Congressman, George Brown, argue that the ATP has addressed assessment issues more effectively than the substantially larger SBIR program. See George E. Brown, Jr. and James Turner, "Reworking the Federal Role in Small Business Research," *Issues in Science and Technology,* vol. XV, no. 4 (Summer 1999).

[24] The recent work of the STEP Board assessing the competitive position of U.S. firms in eleven sectors in the 1980s and today illustrates the inaccuracy of some contemporary assessments and, more broadly, underscores the dangers of complacency. See *U.S. Industry in 2000*, *op.cit., passim.*

Addressing the need for help in meeting the mission of the National Institutes of Standards and Technology, Jeffrey Schloss of the National Human Genome Research Institute, emphasized the ATP's relevance to the Human Genome Project. Given the complexity of mapping the human genome and the enormous amount of data involved, the genome project requires advanced information technology tools and multidisciplinary approaches to technology development. A program that looks across a number of technology areas, such as ATP, is therefore uniquely positioned to contribute. The National Human Genome Research Institute is already partnering with other agencies to create the technologies necessary to exploit our investments in genome research, yet ATP's cross-disciplinary, multi-company approach is especially attractive in meeting the special needs associated with genome research.

Three industry representatives, all of whom had received ATP awards, were asked to discuss the technologies that ATP funded, the review process, and the social benefits of their companies' technologies and to give their views on how to improve the program. In the cases discussed, ATP funded a high-risk technology with commercial potential, a research tool that the company would not pursue on its own, and a cost-cutting technology with industry-wide benefits. In the first case, ATP funded X-Ray Optical Systems, a manufacturer of parallel and convergent beams that allow users (often semiconductor or pharmaceutical firms) to better understand the structure of materials. The company was founded to commercialize technology whose basic research had been conducted in the Soviet Union. Founders of X-Ray Optical reached into personal savings and resources of friends and family in the start-up stages, but they were unable to secure bank or venture financing because the technology was too far from commercial application. An ATP award was an attractive alternative, given that traditional sources were either unavailable or exhausted. Although X-Ray Optical System's first ATP application was rejected, the close technical scrutiny provided by the program proved beneficial. In retrospect, the initial rejection was appropriate. Once the company made the commitment to develop its business and technical plan further, it was able to win an ATP award.

The program also funds proposals by larger companies with widespread applications. For example, at the Honeywell Technology Center, ATP funded a joint Honeywell-SEMATECH-Advanced Micro Devices effort to develop an Advanced Process Control Framework to reduce semiconductor fabrication costs. This is classic "pre-competitive generic technology" in the sense that semiconductor companies compete on chip design, but are burdened with rapidly escalating fabrication costs. A process to reduce costs may be expensive to develop and distract companies from pursuing cutting-edge designs. It is therefore less likely to be undertaken by a single company. Using industry expertise, with ATP's assistance, AMD has reduced fabrication costs by $10 million, and the software developed under the ATP grant has been installed at other semiconductor companies.

At Axys Pharmaceuticals, the company developed a drug development tool called "liquid arrays," a micro-ray technology that permits the company to develop high quality drugs faster and more cheaply. Such a tool is not central to Axys' core business, which is to develop new drugs, not tools to make them. Although promising, liquid array technology was speculative and too expensive for Axys to pursue on its own. Because venture capitalists have severely curtailed funding to the U.S. biotechnology sector, ATP filled an important gap for Axys. Although noting that the ATP administration should try to reduce the paperwork involved in the application process, William Newall added that Axys' development of liquid arrays using the ATP award was further facilitated by Axys being able to retain rights to the intellectual property developed with the award.

From the congressional perspective, Jeff Grove, staff director of the House Committee on Science's Subcommittee on Technology, said he was pleased to hear that the industrial representatives were largely satisfied with the program. He added that he was interested in learning more about how the program could be better implemented. Research done by government auditors and at private think tanks had suggested that program implementation could be improved.

The ATP Evaluation Program

Evaluating ATP has been central to the program since its inception. Rosalie Ruegg, the Director of the ATP's Economic Assessment Office, outlined the ATP evaluation program, saying that the program evaluates projects in light of its congressionally authorized mission to support the creation of generic technologies with widespread economic impact to facilitate their rapid commercialization. Given the need for rapid commercialization, time figures prominently into ATP evaluation; if commercial benefits fall outside the window for a relevant market impact, then the benefits are likely to be seen as insufficient. As ATP conceptualizes evaluation, timely market impact is linked to long-run economic impact. Such long-run impact may take the form of direct marketplace outcomes, such as increased market shares for awardees or easily identifiable industry-wide benefits in a process technology. Indirect impacts are also explored, such as knowledge or institutional effects that may fall outside the boundary of the ATP project. An institutional effect, for example, may be better user-supplier communication channels established in the process of a joint venture carrying out ATP-funded research. These channels may endure long after completion of the ATP project. ATP's Business Reporting System has helped in evaluation of projects, and in-depth case studies have been indispensable in conducting evaluation. New tools and methods for evaluation, concluded Dr. Ruegg, are nonetheless needed. Dr. J.C. Spender reinforced this theme in his comments on Dr. Ruegg's presentation noting that if ATP is an experiment in technology policy, it is also an experiment in evaluation research. He urged that ATP evaluations guard against picking only the "low hanging fruit"; he encouraged researchers present to develop new evaluation tools for ATP and also to take a multidisciplinary approach to the program's evaluation.

Capital Markets and ATP

Even with the most well-thought out evaluation program, policymakers must still consider whether ATP appropriately fills a gap in the access to capital for certain kinds of technologies. In laying out some theoretical issues, Dr. Kenneth Flamm said that even with perfect capital markets, there may be under-investment in R&D because of appropriability problems (i.e., firms investing in R&D do not reap all its benefits). From a venture capitalist perspective, Mr. Todd Spener took a similar view, noting that an ATP award enhances the credibility of a given company's technology. By mitigating technology risk for venture capitalists, the program can help qualify potential candidates for venture funding. It can also provide initial, or "catalyst capital," to help bring in venture funding and the associated management support. In his presentation, Dr. Joshua Lerner pointed out that the venture capital industry, though very flexible, is still relatively small, at some $15 billion annually, in relation to the U.S. economy. Moreover, the venture capital investments are heavily concentrated by sector. For example, 80 percent of current venture funds go to information technologies. Given this concentration, he suggested a program such as ATP can serve as a useful countervailing force to this herding tendency.

Several ATP award recipients described how the grant addressed their needs in ways that traditional funding sources did not. Dr. Mitch Eggers described his company, Genometrix, which makes an electronic DNA chip. When Genometrix first conceived of combining microelectronics and electro-biology in the 1990s, it approached companies such as Texas Instruments and Hewlett Packard for funding. While they found the DNA chip intriguing, the technology was too risky and too far from commercialization for the companies to finance. Genometrix thus turned to ATP for funding, and won $9 million, the largest award given in 1994. Genometrix and its collaborators then were able to obtain $9 million in matching funds. Shortly thereafter, the company received a modest amount of venture financing. In Dr. Egger's view, the venture financing would not have been forthcoming in the absence of the ATP award. Genometrix' technology has in fact proven to have substantial social benefits, as it provides a quick and inexpensive test for whether individuals may be allergic to certain drugs.

For Osiris Therapeutics, a company commercializing mesenchymal stem cell technology for tissue regeneration, the ATP grant allowed it to pursue research in areas that its constrained resources would otherwise prohibit. Although Osiris' technology focuses on cancer therapy, bone, and cartilege regeneration, the company discovered an interesting use for stem cell technology in cardiac muscles. The technology was, however, far from commercialization, and the risk associated with the technology necessitated new resources. Because Osiris receives financing through a strategic partnership with Novartis Pharmaceuticals, it has not sought venture financing. An initial public stock offering was planned, however, market conditions in 1998 led to a postponement. Applying for an ATP award thus became a logical route to pursue, not only because it focused on high-risk technologies, but because it was a competitive grant process. Winning an ATP grant serves has served as a useful bridge to other corporate financing for Osiris' cardiac stem cell application.

Extending Assessment of ATP

Notwithstanding the ATP's already extensive assessment program, extending and improving assessment remains a priority. As NIST's Dr. Maryellen Kelley observed, part of that effort involves collecting the appropriate information from ATP award recipients. Because the typical ATP project takes between three and five years to complete, ATP's business reporting system tracks firm performance during the life of the project and periodically for six years after the award. A key fact about ATP award recipients is that most of them go to groups of firms and organizations collaborating with one another. To the extent that assessment focuses on the ATP grant's impact on recipients, this presents a challenge because there are differential impacts among collaborators. To address that challenge, Dr. Kelley said, case studies are an important assessment tool.

In discussing their research, Dr. William Lehr and Dr. Nicholas Vonortas emphasized the impact of indirect affects and the benefits of case study research. One objective in using case study techniques is to determine the indirect effects of the ATP, e.g., organizational or sectoral learning, which participants said are likely to be a substantial portion of all ATP impacts. By encouraging collaboration through the ATP application process, the program may foster collaboration and learning in ways not directly related to the research eventually undertaken under the ATP grant.

Future Challenges

The day's final panel on future challenges for the ATP focused further on the challenge of assessment, with additional discussion of the program's contribution to a broad and diversified U.S. technology policy. As Dr. Richard Nelson said, the ATP can fill a valuable niche in America's technology policy, yet it should by no means be seen as an all-purpose technology policy instrument. The industry-led character of ATP is a virtue, Dr. Nelson observed, but he cautioned that ATP-funded technologies must be widely disseminated for their full benefits to be realized. He expressed the concern that most of ATP's benefits were accruing to private parties, not the public at large.[25] Dr. Christopher Hill echoed this point, suggesting that the profitability of a given ATP recipient is not the right metric with which to judge the program; rather spillover benefits to the public, as difficult to measure as they may be, is the right standard. Dr. Barry Bozeman remarked that the careful scrutiny and analysis to which ATP has been subject may well be valuable, but will not, by itself, create sufficient political support to sustain the program. He urged ATP officials to continue to modify the program's administrative procedures and management in light of assessment findings.

In his closing remarks, Dr. William Spencer reminded the symposium participants that governments around the world, including the United States government, provide active support for R&D and technology development. In other countries, where the resources involved are sometimes greater, there is little debate about these types of programs; governments simply carry them out. The size and scope of the programs vary across and within countries, and for this reason, they are usually seen as experiments. Technology programs in this country, suggested Dr. Spencer, should be seen as experiments as well. The ongoing assessment of ATP, as well as efforts to improve our ability to carry out such assessment, are not only ways to improve the Advanced Technology Program, they are also an important means to improve future technology policy initiatives.

Charles W. Wessner

---

[25] To address this and related points, the ATP assessment program has commissioned a study by Wesley M. Cohen and John Walsh, "Within and Across Industry Spillovers and Appropriability: A Survey Based Approach." Carnegie Mellon University Working Paper, Pittsburgh, 1998. The study examines the sources of the differences between social and private returns to R&D within industries, examining in particular the role of R&D spillovers.

Welcome

Charles W. Wessner
National Research Council

Dr. Wessner welcomed the conference participants, noting that the conference is being held under the auspices of the Board on Science, Technology, and Economic Policy (STEP), whose chair is Dale Jorgenson of Harvard University and whose vice-chairman is William Spencer of SEMATECH. Among the STEP Board's recent work is a major study on the competitive position of 11 U.S. manufacturing sectors, entitled *U.S. Industry in 2000*; that study was spearheaded by the STEP Board's executive director Dr. Stephen Merrill.[1] The STEP Board also has published *Trends and Challenges in Aerospace Offsets.*[2] This study explores the impact on the U.S. aerospace supply base of compensation packages—also known as offsets—usually associated with the purchase of large systems, such as military aircraft. It was carried out at the request of the White House National Economic Council. Dr. Wessner said that he hoped the day's discussions would be vigorous, adding that many of the audience members were as knowledgeable about the Advanced Technology Program (ATP) as the speakers and panelists.

Turning to the symposium's first speaker, Dr. Wessner said that opening remarks would be delivered by William Spencer, chairman of SEMATECH and a STEP Board member well acquainted with government partnership programs. The SEMATECH consortium, Dr. Wessner noted, was designed to assist U.S. semiconductor manufacturers in gaining technological preeminence in manufacturing processes. The consortium has been a very successful collaborative under-

---

[1] *U.S. Industry in 2000, op.cit.*

[2] Wessner, Charles (ed.), *Trends and Challenges in Aerospace Offsets.* The National Academies Press, Washington D.C., 1999.

taking in an industry noted for its fierce competition. From 1986 to 1990, Dr. Spencer was a senior officer with Xerox Corporation and managed Xerox's worldwide research and development operations. Prior to that, Dr. Spencer managed the Xerox Palo Alto Research Center and held positions at Sandia National Laboratories and Bell Labs. Dr. Wessner added that Dr. Spencer also serves as the vice-chairman of the National Research Council's STEP Board and plays a leadership role in the "Government-Industry Partnerships" project.

Introduction to the Symposium

Bill Spencer
SEMATECH

Dr. Spencer opened by thanking Dr. Wessner for assigning to SEMATECH credit for contributing to the semiconductor industry's turnaround. Dr. Spencer reminded the audience that this is a little like saying that the Xerox Palo Alto Research Center's (PARC) research during his tenure was responsible for the company's subsequent five- or sixfold increase in capitalization. In both instances, the research and development (R&D) of SEMATECH and PARC played a role in the success of the semiconductor industry and Xerox, respectively, but it is always difficult to specify precisely the magnitude of the contribution.

ATP AND THE GOVERNMENT–INDUSTRY PARTNERSHIPS PROJECT

Dr. Spencer welcomed the panelists and the audience and thanked Dr. Wessner and the National Research Council staff for assembling such a distinguished group of speakers for the symposium. The Advanced Technology Program (ATP) symposium is part of a larger STEP Board project called the Government-Industry Partnerships for the Development of New Technologies (GIP). The project has conducted meetings on the Small Business Innovation Research program and on an initiative of Sandia National Laboratories to develop a science and technology park adjacent to the lab. The project is planning an October 1999 conference to explore the biotechnology and computer industries, specifically to compare government-industry partnerships in those sectors.

The ATP is an essential part of the GIP's overall examination of government-industry partnerships. Few people, Dr. Spencer noted, would dispute that technology is one of the major reasons for economic growth. Not many people know how to distinguish the role that technology plays in economic growth from that played by access to capital or other factors, but there is widespread agreement today that technology is key.

Government Role in R&D and Technology Development

Technology comes about because someone has done R&D—either in government, industry, universities, or some combination of the three. Just as the role of technology in economic growth is beyond dispute, Dr. Spencer said that few would argue that government has and should continue to play a crucial role in R&D investment for long-term research. There might be disagreements over the share of the R&D budget that goes to the biological sciences versus the physical sciences, but not many people in Washington would quarrel over the need for government to fund long-term R&D.

In the area of technology development, the government's role is much more controversial. In the semiconductor industry, in which Dr. Spencer has spent much of his career, Dr. Spencer said that countries in other economic regions do not debate whether to fund technology development; they simply do it. Examples in Japan include the Semiconductor Leading Edge Technologies (SELETE) initiative and the Association of Super-Advanced Electronics Technologies (ASET); Europe and Taiwan also have programs to fund semiconductor development, such as the Joint European Submicron Silicon Initiative (JESSI), now the Microelectronic Development for European Applications (MEDEA), and the Hsin Chu Park facility. In each region, these programs are considered experiments. In this country, SEMATECH certainly has been viewed as an experiment. When the semiconductor industry founded SEMATECH in 1987 as a government–industry partnership and then turned it into a fully private activity in 1996, the industry saw the consortium partly as an experiment in partnering, with the hope that lessons learned could be applied more broadly.[1]

Dr. Spencer said that he believed that the ATP falls into the category of an experiment—a large and important one, but an experiment nonetheless. Therefore it is important for all of us in government and industry to understand clearly the program's objectives and history. Most important, it is necessary to focus on what is measurable about the ATP, to draw lessons from the program, and to apply them elsewhere to future government–industry partnerships. This is one of the objectives of the program today.

Dr. Spencer then introduced the symposium's next speaker, Ray Kammer, the Director of the National Institute of Standards and Technology (NIST). Dr. Spencer has had the privilege of knowing Mr. Kammer for a number of years,

---

[1] William J. Spencer and Peter Grindley. "SEMATECH After Five Years: High-Technology Consortia and U.S. Competitiveness." *California Management Review,* Summer, 1993. pp. 9-32.

dating to Mr. Kammer's tenure as a deputy director of NIST and Dr. Spencer's time at Xerox. Since 1997, Mr. Kammer has been the director of NIST, but has been at NIST in some capacity since 1980. Presently, NIST has over 3,300 employees and a budget in excess of $800 million. NIST's laboratories in Gaithersburg, Maryland, and Boulder, Colorado, are among the finest in the world and attract some of the best scientists in the nation. Dr. Spencer was well aware of how the semiconductor industry has benefited from NIST in areas such as metrology. With NIST's outstanding reputation, Dr. Spencer said he was eager to hear Mr. Kammer perspectives on the ATP.

Opening Remarks

Ray Kammer
National Institute of Standards and Technology

Good morning, and thank you all for being here. I would particularly like to thank the National Research Council and Chuck Wessner for arranging this symposium and putting together a strong program on relatively short notice. We appreciate it.

IMPORTANCE OF MEASUREMENT

We measure things at NIST. We have a favorite quotation—it shows up sporadically on bulletin boards and in footnotes—attributed to William, Lord Kelvin. He said that—I will paraphrase freely—when you can measure something and put some numbers to it, then you know something about it, and if you cannot, your understanding of it is of a "meager and unsatisfactory kind."

Since 1901 that statement or something much like it has been a touchstone for us. We are dissatisfied with things we cannot measure, and we work hard to remedy those unhappy situations. Obviously, it is the philosophical basis for the NIST Measurement and Standards Laboratories, the research core of our agency. It plays a strong role as well in the activities of our Manufacturing Extension Partnership and the Baldrige National Quality Program.

So of course when we received the assignment to create and manage the Advanced Technology Program (ATP), one of the first thoughts was, "Fine. How do we measure it?" We knew several things before undertaking this task:

- The ATP presents a unique measurement challenge, not just for NIST but for government, industry, and the economics community.
- We know that technological innovation, by and large, is a good thing.

- Advanced technology has sustained our leadership in the global community. It has accounted for over 50 percent of U.S. economic growth since the Second World War.

The Advanced Technology Program was established by Congress to help spur this economic growth. Congress created a mechanism to encourage and nourish economically valuable technologies that might otherwise go untried—or be exploited by our global competitors—because the R&D risks were too high to be supported entirely by the private sector. The ATP practices a sort of economic jujitsu, applying relatively small, highly leveraged investments against the potential for major economic impacts.

Can it work? Well, sure. The classic existence proof is the Internet—the relatively modest early investments by the Department of Defense (DoD) and universities are utterly dwarfed by today's economic impact.

Yet this raises another set of questions:

- How do you measure the worth of technological innovation?
- How do you measure its impact on the economy of a nation?
- How do you *predict* that impact five years out? Ten years out? Ten years ago few people would have been sufficiently insane to predict the current role that the Internet plays in the national economy.

The ATP measurement challenge emanates from the program's mission to create long-range, broad-based economic benefits. Long range means sometime out in the future. Although, ultimately, we will perform retrospective analyses, we cannot wait until then. Broad-based economic benefits mean tracking and measuring impacts that go well beyond the individual company or companies that did the original work. We need to measure or credibly estimate the macroeconomic effects of a fundamentally microeconomic program. Finally, we need to make credible predictions based on those measurements and estimates.

BACKGROUND ON PROGRAM ASSESSMENT

So how do we assess our work in the intervening time between the short and the long term? At NIST, measurement and evaluation have been part of the ATP from the beginning. The first major report appeared in 1993, a survey examining the early impacts on participating companies of the first 11 ATP projects after a year of work. The ATP established its Economic Assessment Office to oversee a wide range of data-gathering and analysis efforts including basic data collection, case studies, surveys, and macroeconomic modeling. The ATP's business reporting system, for example, uses an innovative electronic survey form to gather quarterly information on active projects and follow-up data after completion, tracking their progress toward achieving business and economic goals.

Our research universe encompasses the 431 projects selected by the ATP for funding to date. We can tell a lot about the ATP just from the project profiles:

- Industry commits significant resources to these endeavors, making it a true partnership. The ATP committed to $1.386 billion in funding for the projects selected to date, less than half the projected $2.783 billion budget for the planned research.
- Diversified joint ventures play an important role in the program. These 431 projects involve more than 1,000 participating organizations, including more than 125 universities and nearly 20 national laboratories.
- Small business competes effectively in the merit-based selection process. More than half of the projects are led by small businesses.

Surveys and the business reporting system tell us more about the ATP's near-term impact on participants:

- The program is stimulating collaboration, encouraging more and more research joint ventures.
- The ATP is accelerating the development of high-risk technologies. Eighty-six percent of project participants in one study said that they were ahead in their R&D cycle after just one to two years of ATP funding. Thirty-nine percent of those were ahead because they would not have undertaken the project at all without the ATP.
- ATP is fostering the development of leapfrog technologies that go well beyond simple incremental advances in the state of the art. Thirty-seven percent of ATP-developed technologies in a recent study were "new to the world" innovations.
- These technologies have broad potential applications. Companies report identifying an average of 4.5 applications per project.
- Grant recipients have committed their own resources to commercialize more than 100 new products, processes, or services based on ATP technologies.

RECENT ASSESSMENT OF THE PROGRAM'S ECONOMIC BENEFITS

The ATP is probably the most thoroughly studied program of its kind in the world. My current stack of reports, studies, analyses, and analyses of analyses on the ATP is about 9.5 centimeters deep, or about a centimeter or so of report for every year of the program's existence. I am not sure the collection is complete.

In addition to near-term results, we have applied macroeconomic models in an attempt to look at potential long-range impacts. In 1996, CONSAD Research

Corporation used a 53-sector macroeconomic model developed by Regional Economic Models, Inc., to estimate potential long-range impacts of a single ATP project. This was a joint venture under the Auto Body Consortium, a coalition of small- and medium-sized auto industry suppliers working with Chrysler and GM as well as the University of Michigan and Wayne State University. The project developed a suite of process monitoring and control technologies to reduce dimensional variations—fit and finish problems—in auto bodies on the assembly line. These technologies led directly to

- lower production costs,
- lower product maintenance costs,
- improved product quality, and
- reduced cycle time to launch new models.

On the basis of their modeling, CONSAD estimated the total impact of this project on the U.S. economy—counting all of the industrial sectors affected by the auto industry—at more than $3 billion in the year 2000.

Last year the Research Triangle Institute (RTI) Center for Economics Research completed a study that was intended to develop a prototype methodology for predicting the long-term social benefits of public investment in technology development. RTI analyzed probable partial outcomes for seven ATP projects in the field of tissue engineering. These were technologies to make "template" prostheses derived from biomaterials to assist the body in rebuilding lost tissue, to produce implantable cells that generate key human hormones and other bioactive agents, such as insulin for diabetics, and others.

RTI used a procedure to calculate the expected social return on public investment—the extent to which the nation is better off as a result of the ATP. This includes not only the private return to the innovating company, but also the value of the technology to the nation at large—lower health care costs, for example, or improvements in medical outcomes and quality of life for the patients. The ATP expects to invest a total of $15.5 million in the seven projects covered in the RTI study. RTI calculated the expected social return on the ATP's investment in these technologies at $34 *billion* in net present value over a 20-year period. That is a predicted social rate of return on the ATP investment of *115 percent annually over 20 years.* This is not a bad return.

You might be interested to know that in both cases we urged the researchers to use conservative assumptions. Dedicated optimists could come up with even higher figures. I have asked ATP officials to be careful about touting these results because they are so striking.

I cite these results not because I necessarily expect you to accept them at face value. Rather I want to emphasize the magnitude, and the difficulty, of the task we face. There are major issues involved in the use of macroeconomic models on a program of this size of the ATP, but we need to ask these predictive questions. These reports represent the sort of analyses we need to have.

ASSESSING COMPLETED PROJECTS

Today we are adding a new report to the stack, a summary study by economist William F. Long, called "Performance of Completed Projects," which examines the first set of completed ATP projects.[3] This is the first comprehensive review of the outcomes to date of the ATP portfolio, and the first of a series of studies following up on the results of ATP investments. Dr. Long's report covers the 38 projects that were completed as of the end of March 1997, documenting research accomplishments, subsequent work by the companies to commercialize the results, and near-term outlooks for the successful technologies. It also looks at 12 projects that were terminated or canceled during that same period (out of 280 projects selected). This is a respectable rate for a program that concentrates on high-risk research, and we have learned some useful things from the failures. It is, as Secretary of Commerce William Daley said in his announcement, "a portrait of a program that works."

The program's current portfolio covers the high-technology terrain very thoroughly. For example, there is a process that merges tissue engineering and textile weaving to help regenerate lost or damaged tissue in the body. There is an application of high-temperature superconductors to improve cellular phone service. We are funding a desktop bioreactor capable of growing large amounts of human stem cells isolated from bone marrow for cell replacement therapy—now in clinical trials. Already in commercial use is an ATP-funded computer programming tool to simplify the task of writing software for parallel-processing computers. Finally, there is a novel technology for processing very large semiconductor wafers. This innovation, developed by Diamond Semiconductor Group, has made the United States the first in the market with processing equipment for the next generation of 300-mm semiconductor wafers. These are just some of technologies that the nation has, here and now, because of the ATP.

As the ATP enters its tenth year, we face some significant challenges. At the same time, the ATP, as Secretary Daley says, is working. We are, without a doubt, having an impact. Dr. Long's report is only the most recent testament to that. However, we need to grow the ATP to a level consistent with the program's fundamental mission of economic growth for the nation. Just what that level should be is a matter for debate, but as an example, I would point to the only other major technology funding program with demonstrable success and national impact. That is the Defense Advanced Research Projects Agency, with a budget in the neighborhood of $2 billion.

---

[3] William F. Long, *Advanced Technology Program: Performance of Completed Projects. Status Report Number 1,* U.S. Department of Commerce: NIST Special Publication 950-1, March, 1999.

To support this, we need the data. The challenge is to document how the ATP affects the economy, and by how much. The challenge is to do so in a rigorous and credible way that will satisfy the requirements of the public policy makers in Congress and the administration. Our goal in this workshop is to address those measurement and assessment issues. How can we best assess the ATP? What data do we need to do that? How can we get the data we need? I will leave you to it. We appreciate your help and look forward to your insights. Thank you.

Panel I: History and Current Legislative Perspective on the ATP Program

INTRODUCTION

Clark McFadden
Dewey Ballantine

Mr. McFadden welcomed the first panel by noting that the Advanced Technology Program (ATP) is one of the most visible government–industry partnership programs and therefore fits squarely into the charge of the Board on Science, Technology, and Economic Policy's (STEP) project on Government–Industry Partnerships for the Development of New Technologies. The ATP is a prominent government–industry partnership that was founded as part of an explicit "national effort to help accelerate the commercialization of high-risk broad benefit enabling technologies with significant commercial implications." That is an ambitious goal, Mr. McFadden observed, and moreover, the program was born in an atmosphere of great controversy and attention. Today, this panel examines the program from the perspective of its history, purpose, and objectives. Dr. Christopher Hill of George Mason University begins the discussion; like the panelists to follow him in discussing the program, Dr. Hill brings exceptional expertise to the discussion of the program's history.

AN OVERVIEW OF THE ATP'S HISTORY AND OBJECTIVES

Christopher Hill
George Mason University

Dr. Hill opened his remarks by expressing his hope that the symposium would bring new information and insights to bear on the ATP. His task was to provide, as a basis for further discussion, some background on where the ATP came from and why it exists. Dr. Hill noted that he was involved with the program in its formative stages and that his views would represent "one man's perspective" on the ATP's origin.

Economic Context of the ATP's Origins

The ATP arose out of a confluence of several forces at a particular point in time in the late 1980s, but whose initial causes date prior to that time. Beginning in the 1970s with the Arab oil embargo and extending into the 1980s, Dr. Hill recalled the growing sense of crisis in the United States, a sense that perhaps America's best days were behind it. There was a widespread perception that "we must do something" to restore prior levels of income and productivity growth. One defining event of that period, Dr. Hill said, was the Federal Reserve's decision in 1979 to focus on money supply growth as a means to control inflation. Although this policy successfully addressed inflation, it also caused a severe recession that saw unemployment rise to 11 percent. This triggered the great debate on industrial policy in the mid-1980s.

An additional consequence of the Federal Reserve's tight monetary policy, Dr. Hill said, was a rise in interest rates, which in turn strengthened the dollar and created a very high trade deficit. The trade deficit extended beyond traditional manufacturing goods to high-technology goods. A trade deficit in the high-techology sector had not existed since the Commerce Department began compiling figures for this sector in the 1960s. Research-intensive industries in the United States, such as electronics and semiconductors, began to see their world market shares decline.

The Japanese Challenge

There were some highly visible instances in which promising U.S. start-up firms were unable to procure financing domestically, and therefore turned to Japanese firms for capital to grow. This suggested that there was something fundamentally unworkable about the American system of risk capital for high-technology start-ups, and that this country had to do something about it. There was the manifest failure of U.S. firms to commercialize the videocassette recorder

(VCR); Japanese firms successfully commercialized this market and during this period no VCRs in U.S. homes were made by U.S. firms.

In the mid-1980s, Dr. Hill continued, Japanese economic success was attributed in part to government-supported cooperative research and development (R&D) programs in Japan. Revisionists now claim that too much credit was given to Japanese cooperative R&D programs for Japan's overall economic success, but certainly conventional wisdom at that time placed great emphasis on Japanese government-funded cooperative R&D programs. This created great enthusiasm in the United States for R&D partnerships involving companies, universities, and federal laboratories.

By 1987, it became clear that a trade bill would have to be passed because the Export Administration Act was expiring, as was the President's fast-track trade negotiating authority. The need to have a bill invited a large number of amendments and miscellaneous titles, which in the end became the Omnibus Trade and Competitiveness Act, an enormous bill in excess of 4,000 pages.

Technology Policy Context

In this context, the Advanced Technology Program was born, but the context was no guarantee that a program such as the ATP would be created. Why did this specific program come into being? In Dr. Hill's opinion, the program was created because, in the eyes of its advocates, it codified an idea whose time had come. The seeds of the ATP were sown at least 25 years earlier during the Kennedy administration, which advocated the creation of a civilian industrial technology program whereby the government would fund a series of cooperative R&D programs to be operated by nonprofit institutions to strengthen the technology base of lagging sectors. Because that was a period of robust economic growth, problems in sectors such as electronics, autos, and steel were not foreseen. The Kennedy initiative sought to address sectors such as building materials, construction, textiles, and shoes. However, this initiative was defeated, in part because the industries that were the intended beneficiaries opposed the program.

Although the initiative failed, it did renew a dialogue about the proper government role in civilian technology development. This dialogue meandered throughout the late 1960s and through the Nixon and Ford administrations. The energy crisis of the early 1970s resulted in a number of government research programs to either conserve energy or expand supply. In this context, the notion of government support for industrial R&D to address specific nonmilitary economic problems was not alien.

The Carter administration's domestic policy review of industrial innovation during 1978–1979 was the next manifestation of the idea of government support for civilian industrial research. The objective was to search for ways to resuscitate U.S. industry, given the era's high unemployment, high inflation, and slow economic growth. There were a wide range of diagnoses and proposed solutions to the economic slowdown, and one widely explored area was America's apparently declining capacity for industrial innovation. The administration produced a series of recommendations in 1980 to address these issues, but most were ignored when Reagan took office.

Growth of Cooperation During the 1980s

Nonetheless, some action resulted from this debate, namely the Stevenson–Wydler Technology Innovation Act of 1980. This embodied some of the recommendations of the Carter dialogue, including authorization of the establishment of centers of industrial technology with government funding to aid industry. The Reagan administration, however, did not fund these centers, but the authority still remains in the law.

In the mid-1980s, the idea of government support for cooperative R&D emerged on an ad hoc sector-by-sector basis. Examples include SEMATECH, the National Center for Manufacturing Sciences, and other efforts to help the steel and aluminum industries. This idea emerged in the private sector as well, with the creation of the Microelectronics and Computer Technology Corporation, which was advocated by Bill Norris of Control Data Corporation. Norris's advocacy of cooperation was very strong, and he pushed the idea whenever he could.

The belief in the need for government support for precompetitive or generic research was fairly well developed when the trade bill came along in 1987. Every committee in Congress wanted to have a piece of the trade bill, and the House Committee on Science was no exception. The ATP was the Science Committee's main contribution to the trade bill.

Politics of the ATP

Dr. Hill then turned to some of the politics accompanying the ATP. First, the business groups that were likely beneficiaries of the program initially were, in Dr. Hill's view, somewhere between "oblivious, lukewarm, and indifferent" to the ATP initiative. Dr. Hill was working on Capitol Hill at the time, and he recalled that it was difficult to find witnesses from industry to testify on what an ATP might do. It was not something for which the National Association of Manufacturers or the Chamber of Commerce was prepared to mount a large lobbying campaign. The ATP was not seen as an initiative of a particular trade association. Rather, congressional staff drove the initiative.

Second, Dr. Hill believed that the ATP would never have been enacted had it stood alone, apart from the larger trade bill. Had it had the chance, the Reagan administration would have vetoed the program.

When President Bush took office, his administration implemented the ATP at the level of $10 million in its first year. This laid the groundwork for future debates about the program's growth path. Ten million dollars was not even experimental, but more of a "baby step" in program development, and little more than an opportunity to develop rules and regulations. The Bush administration was deeply divided on the program: Some officials in the Commerce Department vigorously advocated the initiative, but powerful officials in the White House, such as Chief of Staff John Sununu and Chairman of the Council of Economic Advisors Michael Boskin opposed the program. This result was that the program's funding rose slowly in the Bush Administration, to over $60 million annually by the end of the administration.

When President Clinton came into office, many people thought this ushered in an era new initiatives in technology policy. By and large, of course, this did not happen. In the campaign, the Clinton–Gore team embraced ideas such as the ATP and, in March 1993, in a $16 billion stimulus package, the ATP played a prominent role. However, the stimulus package was defeated by a Congress controlled by Democrats. The most focused opposition, however, came from Republicans, which perhaps should not be a surprise. Dr. Hill noted that the intense Republican opposition to anything that President Clinton personally endorsed was remarkable, even by Washington standards. And the ATP suffered from that. The anticipated growth path for the ATP, to as high as $1 billion per year, further fueled opposition to the program.

After the 1994 elections, which brought a Republican majority to Congress skeptical of many federal programs, the ATP went into what might be described as survival mode. The issue was no longer how to expand the program or whether to search for new things to do, but rather how to protect the program from extinction. As part of that effort, NIST implemented the very extensive analytical program that Mr. Kammer described and which will be the subject of much discussion today. For the size of the program, Dr. Hill observed that, with the possible exception of Head Start, ATP is the most rigorously studied, open, and closely scrutinized program of any era, in any country. If there is a program that has been more extensively evaluated, Dr. Hill said he hoped that someone would bring that up in the day's discussions.

Current Outlook

In the politics of the program, things have settled down considerably since the departure of Representative Robert Walker (R-Pennsylvania), the former Chairman of the House Committee on Science. He was one of the program's most vocal critics, and certainly the one in the best position to act on his views. Dr. Hill also observed that the drive to "do something to help industry" has also largely subsided. After all, we are in a remarkable period of industrial renaissance, with corporate profits very healthy and productivity growing at more than 2 percent per year. Although the trade deficit remains high, it seems to have almost disappeared from public concern. We have budget surpluses "as far as the eye can see" and 4.3 percent unemployment. The need for action appears to have gone away.

What has happened is what always happened when the economy is strong; technology policy has disappeared from the national agenda. Dr. Hill recalled a chart developed by Chuck Larson, president of the Industrial Research Institute, which shows technology policy initiatives over the past three decades. The chart is blank after 1992; there have been no legislative initiatives since then. Of course, one might attribute that to the election of a small-government, anti-interventionist, anti-industrial policy Democratic administration, but that does not seem to be the right explanation. Rather, the remarkable performance of U.S. industry is the more likely answer. This performance has almost nothing to do with the ATP, and to the extent that government programs have contributed to this growth, the Defense Advanced Research Projects Agency (DARPA) has played the main role.

Coincidental with the seven years of strong economic growth, the nation, then, has had few technology policy initiatives or legislation. Dr. Hill concluded by observing that we probably will have to wait until the next recession to again have a serious discussion of technology policy.

PERSPECTIVES ON THE PROGRAM

Loren Yager
General Accounting Office

Dr. Yager began by thanking the Academy for holding the symposium and particularly for highlighting the evaluation that the ATP conducts. He commended the program for the extent of its self-evaluation, that being one of its most positive aspects. He added that the ATP certainly qualifies as a valuable case study in federal technology policy.

The ATP in Hindsight

Dr. Yager suggested to the audience that it would be useful to think back 10 years, to a time when the ATP had been authorized, but funding levels had not yet been set. We could imagine being in a meeting whose purpose was to decide ATP funding levels, and much of the discussion would have revolved around the incredible performance of the Japanese economy. Some characteristics of the Japanese economy would have been discussed, including how the Japanese government could influence or subsidize R&D investment and how the unique relationship between government and industry had enabled Japan to invest in long-term high-risk R&D at a greater rate than the United States could invest. There also would have been a lot of talk about the poor performance of the U.S. economy, particularly the high-technology sector.

However, imagine sitting in that room 10 years ago and having some information that others did not have. Instead of seeing a Japanese juggernaut going forward into the future, you could see that Japan would become an economic laggard. Japanese economic growth, which averaged 3.4 percent per year during the 1990s, would fall to an average 2.1 percent growth rate from 1990 to 1998. Japanese unemployment would more than double, and the Japanese stock market, as measured by the Nikkei Index, would fall during the late 1990s to less than half its mid-1980s' level.

Let us suppose that you also knew that U.S. economic performance would undergo some turbulence during the early 1990s, but would turn around dramatically thereafter. U.S. GDP growth would average 3 percent in the seven years after 1991; unemployment would fall to levels once thought unattainable, and reach a milestone in early 1999 when U.S. and Japanese unemployment rates were both 4.3 percent. Finally, you also would know that, by 1998, the major U.S. stock indexes would be three times their late 1980s' levels, and that an entirely new industry would have been established around the Internet.

If such an imaginary meeting were taking place in New York, Dr. Yager observed, and this information were available, everyone would leave the room to call their investment advisors. If the meeting were in Washington, D.C., perhaps few people would leave the room but, Dr. Yager argued, few of those remaining would make the decision to fund the ATP on the basis that the program would emulate the Japanese system. Few people with that information would make the decision to fund ATP because they believed U.S. capital markets were broken and in desperate need of repair.

Rationale for the ATP

Armed with this information, Dr. Yager said that most people would make the ATP funding decision on the basis of

- the recognition that market imperfections result in underinvestment in certain types of R&D,
- a weighing of whether the ATP could resolve that problem.

Dr. Yager argued that even many of the most civic-minded people in that room would have left at that point. Even with all the information about the U.S. and Japanese economies, as well as market imperfections in R&D, there would not have been enough information available to make the decision to fund the ATP. The few people who might have stayed in the room probably would have wished for a few years of data on the operations of the program. That would have put them in a position to make an informed decision to assess whether the ATP addressed the R&D underinvestment problem.

Given that ATP has been funded and that it has generated data on its operations, one might argue that the remaining people in the meeting have had their wish fulfilled in the past 10 years. Although ATP has built up a track record on its operations over time, Dr. Yager said that it has come at the expense of a lot of people being "locked in a room talking about the ATP." A great deal of evaluation has been done on the ATP, much of it by the ATP and the General Accounting Office (GAO) and the National Bureau of Economic Research, and some from the American Enterprise Institute. Numerous congressional hearings have been held as well. From an analyst's standpoint, this wealth of information is good news. Moreover, the performance of the U.S. and Japanese economies is no longer the focus when discussing the ATP. Therefore, we now can focus on whether the program addresses the underinvestment in certain types of R&D. Overall, this makes it a much better time to be a room talking about the program's potential.

Richard Russell
House Committee on Science

Mr. Russell began by observing that the level of controversy surrounding the ATP has subsided markedly in the past few years. The program has become a known quantity, and there are likely to be far fewer disagreements about the program than in the past.

The House Committee on Science, of which Mr. Russell is the deputy chief of staff, has not yet begun work on the National Institute of Standards and Technology (NIST) authorization; therefore, it is difficult to discuss specifics for 1999. Mr. Russell recommended that interested audience members look at H.R. 1274, the NIST authorization bill passed by the previous Congress, for a sense of the Science Committee's direction for this year.

The two main components of H.R. 1274 that address NIST are a change in the matching requirements for ATP—a 60 percent match for all ATP grants except those for small businesses is part of the bill—and language to ensure that ATP funds do not displace private capital. This is a reaction to numerous GAO reports finding that many ATP applicants were not searching for private capital before turning to ATP. Both provisions were critical components of H.R. 1274. The Science Committee's "Views and Estimates" document for this year, which is supplied to the Budget Committee as part of the budget process, states that, without the reforms embodied in H.R. 1274, the Science Committee could not support funding for new ATP grants in the upcoming budget cycle.

David Goldston
Office of Representative Sherwood Boehlert

Congressional Role in the ATP Debate

Mr. Goldston said that, like others on the panel, he was involved with the ATP from the beginning and that he would focus his remarks on the role of ATP evaluation. He recalled Ray Kammer's opening remarks in which Mr. Kammer said that one hope for today's symposium was that the deliberations might yield insight into the proper size for the ATP. Mr. Goldston said that, in his opinion, Congress would not provide much guidance on that question. The prevailing sentiment in Congress is to answer that question in one of two ways: Either the ATP should be funded as much as possible or not at all. Neither answer is helpful in terms of analyzing the economics of the program and the role it should play in the economy. This is an area in which Congress needs outside advice, which then should be filtered through the political process to settle on the program's funding level. Congress itself is not likely to engage in a substantive debate on the optimal size of the program.

Mr. Goldston observed that arguments about the ATP have become familiar over the years, and can be placed into one of two categories:

- People who do not like the ATP because they distrust government, and
- People who do not like the ATP because they distrust industry.

In the early years of the program, these categories broke out largely along party lines, with Republican in the former, saying that government should not "pick winners and losers" and Democrats in the latter, saying that government should not subsidize big business. These alignments have shifted a bit, in that libertarians, who align themselves with Republicans, argue that neither industry nor government can be trusted.

In time, primarily because concern over Japan has subsided, the argument in Congress has become quieter and calmer. Debate on the ATP has centered on budget necessities and a certain amount of "grudge match" dynamics between Congress and the administration. In the current budget environment, in which budget caps are still operative, the Clinton administration would like to increase funding for defense and education. This leaves less money for programs such as the ATP and this moves the debate on the ATP to how much money it should receive, not to whether government's role in funding the ATP is appropriate. An important question also becomes the priority that Congress and the administration place on the ATP across NIST's other functions and other government functions.

Importance of the ATP Evaluation

In this context, the numerous evaluations of the ATP become more important, and it is worth asking how useful the evaluations are to decision-makers. Mr. Goldston noted that it is a mixed blessing for the ATP to be one of the most measured programs in history. Although it is hard to argue that evaluation is undesirable, one must ask whether too much has been done too early. Too much evaluation may result in "pulling flowers out of the ground to see how their roots are growing." Had DARPA been subject to such scrutiny in its formative years, Mr. Goldston wondered whether the agency would have produced the excellent results that it has. For the ATP, the evaluations generally do not address the real question that Congress would like answered, which is the net economic benefit of the program. Rather, the ATP evaluations explore whether a particular project would have been undertaken without government funding and, if the project had been undertaken, whether the capital invested would have been put to better use in the private sector. Both questions are extremely difficult to answer and tend to draw the discussion into "religious debates among people of different articles of faith." That is why, concluded Mr. Goldston, that the ATP debate will continue in spite of all the evaluations.

Claude Barfield
American Enterprise Institute

Dr. Barfield said that he would focus his remarks on the ATP's evaluation, and specifically on what evaluation of the ATP should accomplish. The ATP was created after a decade in which there was bipartisan agreement that more had to be done in this country to commercialize R&D and put R&D more squarely in the innovation process. The ATP was an outgrowth of the Stevenson–Wydler mindset that encouraged the use of existing technology in the marketplace, but with the difference that the ATP was designed to create new technologies for commercial purposes. The ideas were essentially the same.

Rationale Underlying the ATP Evaluation

However, the ideas underpinning the ATP, Stevenson–Wydler, and the Bayh–Dole Act presented problems that still have not been addressed fully. The various rationales that have been put forward for program such as the ATP deserve close scrutiny. Dr. Barfield said that he did not dispute the notion that some of the projects undertaken by the ATP have what economists call "public good" characteristics, that is, the projects are nonexcludable and nonrivalrous in nature. This is the strongest rationale for government funding of R&D for projects that extend even beyond basic research.

From a program design and evaluation perspective, this rationale would suggest that the program should encourage collaboration among industry, or other activities that would widely diffuse technologies funded by the ATP. This, in turn, leads to questions about intellectual property provisions in ATP and legislation such as the Bayh–Dole Act. From society's point of view, when industry comes to government for R&D assistance, industry cannot have it both ways. Industry cannot turn to government for an R&D subsidy by arguing that the social costs exceed the private ones, and at the same time want full intellectual property protection for government-funded R&D projects. Dr. Barfield suggested that intellectual property rights be weakened for government-funded R&D or, more drastically, the government should have "march-in" rights for the technology that taxpayers fund. Otherwise, the case for government R&D support is diminished.

ATP and Commercialization

A second set of issues with the ATP has to do with the program's emphasis on commercialization. ATP awardees are asked to provide commercialization plans, and much of the ATP evaluation discusses the commercial benefits of the program. However, the more clearly one can identify the commercial benefits of the program, Dr. Barfield said, the more the question of why the government is supporting such activity in the first place comes into play.

Dr. Barfield observed that there is a great deal of attention in ATP documents devoted to speeding up the "cycle time" of R&D and commercialization. That sort of rationale assumes that the ATP is purely a commercialization program, which Dr. Barfield believes is a much weaker rationale for the program than the public-good argument. Addressing the examples raised by Mr. Kammer, Dr. Barfield argued that these are cases in which the private sector should bear the R&D costs entirely on its own. The projects involved efforts with clear ending points and clear market-demand meaning; if he fully understood the example, Dr. Barfield said, the private sector should have funded the projects.

In concluding, Dr. Barfield reiterated that he believed that ATP should encourage collaboration among companies so as to foster R&D dissemination and rarely, if ever, fund a single company. Moreover, the intellectual property protection afforded the private sector in the ATP projects should be rethought.

James Turner
House Committee on Science

Mr. Turner opened by observing that the differences among panelists on the ATP are not that great, and added that he agreed with Claude Barfield on several aspects of the program. Mr. Turner said that, in his comments, he wanted to convey a sense of how congressional staff and elected officials thought about the program when it was created a decade ago. Many of the same themes emerge in debates today. Mr. Turner identified six issues that were debated "long and hard" in authorizing the program.

Context and Values

Congress looked at three models, in the aviation, agriculture, and pharmaceutical sectors, in which government played a large funding role. It was thought that relying on the Department of Defense budget for new civilian technologies was no longer sustainable; the ATP was consequently an experiment designed to address new technology development head-on. In terms of values, Congress realized that there was not an infinite amount of money, and for that reason every effort was made to make the grant process as nonpolitical as possible. Senator Ernest Hollings deserves the greatest credit for insulating the ATP from politics; even the first $10 million in ATP appropriations faced pressure from members of Congress for funding for home-district universities or companies. Three administrations have successfully shielded the ATP grant-making process from political pressure.

Limited Targets

The term precompetitive generic technologies was used to describe the types of technologies to be funded. It was apparent to congressional staff and others in the policy community that the Vannevar Bush notion of innovation, that is, the linear model in which innovation moves from basic science in the lab, to development, to the marketplace, was no longer appropriate. In searching for a program that would respond to quicker innovation cycles, drafters of the ATP decided to concentrate on generic technologies that affect entire industries. That is why the original statute contained a preference for joint ventures.

Maximizing Benefits to U.S. Companies

The clear intent of the statute was to aid U.S. companies, which required addressing the difficult question of defining what that meant. It was decided that focusing on where the jobs are, especially the research jobs, was more important than where the chief executive officer of a company is located.

Industry-Led

Mr. Turner recalled living through the Synfuels program of the late 1970s, in which government took the lead in shaping technology development. This proved unsuccessful, and Congress wanted to avoid that mistake with this program. Projects that had "honest" cost sharing, in which a company really put in 50 percent of funds, would attract the attention of company executives and increase the chances of success.

Evaluation

At the outset, drafters of ATP legislation thought that ongoing evaluation had to be an integral part of the program. As today's symposium illustrates, evaluation has remained a prominent theme in the ATP.

In concluding, Mr. Turner recommended that we look 10 years into the future as we evaluate the ATP. Although the U.S. economy is strong now, Mr. Turner was unwilling to rule out future industrial challenges from the Japanese or the Europeans. The rapid pace of economic change creates great uncertainty; in Mr. Turner's opinion, we do not have enough information to determine whether the current U.S. economic boom is a bubble that might burst or the sign of fundamental long-term strength. Given these uncertainties, Mr. Turner recommended that we make sure that the ATP and other programs are flexible enough to respond to future challenges.

QUESTIONS FROM THE AUDIENCE

Dr. Wessner noted that world economic conditions had changed dramatically in the past 10 years; few would have guessed 10 years ago that the Japanese economy would suffer a severe and extended recession, and few might have guessed that the U.S. economy would see such a resurgence. Given the possibility of unforeseeable changes in the next 10 years, how, if at all, should the ATP be changed?

Dr. Barfield responded that whatever surprising changes the economy undergoes in the next 10 years, the ATP is unlikely to be part of the solution. The ATP is not large enough to have been relevant to the U.S. resurgence in the past 10 years, and is not likely to become large enough to address new challenges at the macroeconomic level. Mr. Goldston agreed with Dr. Barfield, and added that the program really has to stand or fall on whether it provides social benefits. Concerns about foreign economic threats were a key part of the context of the ATP's development, but Mr. Goldston thought it would be better if that sort of discourse faded from the ATP debate.

In addressing Dr. Barfield's earlier comments, Mr. Goldston acknowledged that there were inherent contradictions in the ATP, and to address this, Congress used the term "precompetitive generic research" in drafting the legislation. Mr. Goldston said he believed that no one had a good definition of the term, and that it is one of those "we'll know it when we see it" kinds of phrases. Another contradiction in the program is that the ATP was driven by the perception that companies had insufficient resources to commercialize products; yet the ATP does not deal with commercialization. The ATP really harkens back to the civilian DARPA idea. However, when we evaluate the ATP, we still look at commercialization; this is not a bad thing, although it does reflect some of the program's initial contradictions.

Dr. Richard Nelson of Columbia University asked panelists, especially congressional staffers, how the ATP has changed over its 10-year life. Mr. Turner responded that the program today is 20 times bigger than when it started and 3 to 4 times bigger than at the end of the Bush administration. With a $10 million or $60 million program, it is almost impossible to focus on specific technology areas; the program simply funded the best ideas that came forward. As the program grew, some structure was imposed in terms of technology areas to be funded, and this was simply not thought of in the ATP's early years.

A questioner asked about the tension between the desire to have ATP generate externalities and the fact that ATP recipients have intellectual property rights to ATP-funded projects. The questioner observed that patent rights are not perfect and, even in the presence of strong intellectual property rights, it seems that economists agree that the social return to R&D is high. Moreover, many innovations could not be commercialized in the absence of patent protection. In response, Dr. Barfield agreed that there was a balance to be struck, that is, some intellectual property protection was necessary for ATP awardees even though perfect protection might undermine the goal of technology diffusion. Dr. Barfield added that it seemed contradictory for a company to seek an ATP grant because the private return was not fully appropriable, but at the same time ask to "fence off" that return through intellectual property protection.

Panel II: Program Objectives

INTRODUCTION

Henry Kelly
White House Office of Science and Technology Policy

This session is designed to talk about the operation and implementation of the Advanced Technology Program (ATP), which is, said Dr. Kelly, “where the rubber hits the road” for any program. The operation of the program has to reflect the original purposes of the ATP, and the clear goal of the ATP is to put public research and development (R&D) money in places in which the economy can benefit from the knowledge spillovers that R&D creates.

The Clinton Administration’s Perspective

The Clinton administration remains very interested in the program because of the spillovers that it generates for the economy. It is an enormously complex task to maximize the spillovers from R&D investment, but it is worth undertaking because the spillovers benefit not only other firms in the sector in which an ATP recipient operates, but also firms in the entire economy. As an example, Dr. Kelly noted that it is probably fair to say that Wal-Mart has made more money off of the integrated circuit than its inventors.

There are social goals associated with R&D spillovers. Much of the research into new industrial processes—motivated initially by purely economic objectives—has subsequently made great contributions to environmental protection. This is because efficiency in production usually means minimization of waste.

Finally, there is an educational and training aspect to spillovers: R&D, particularly when conducted jointly among companies and universities, builds the internal capacity of firms to be innovative. In the arena of human capital, these spillovers are huge and have fueled a great deal of this country's economic growth.

The program has taken on a tough set of problems, Dr. Kelly continued, and although the problems are difficult, the administration believes that it is well worth the effort to have the ATP address them. For instance, some research problems cannot be assigned easily to mission agencies, such as the National Institutes of Health or the Department of Agriculture. Some technology initiatives extend across a number or fields, and the ATP has played an indispensable role in addressing such R&D problems.

Moreover, in achieving a balanced portfolio of risks in R&D projects—from relatively risky university research at the frontiers of new knowledge to less risky advances in industrial process—the presence of the ATP has helped to spread that risk across agencies.

Implementation

The challenge, continued Dr. Kelly, is to take this complex set of objectives and make them operational. It has been said today that the ATP is an experiment and, as with any experiment, it is important to make adjustments along the way. From the perspective of an official at the White House Office of Technology Policy, Dr. Kelly said that he was very gratified that ATP management has made adjustments in the program in the past several years. Last year, for example, an evaluation yielded changes in how the ATP treats the participation of small businesses and states in the program.

Evaluation of public R&D programs faces a unique challenge, in that federal support for research involves provision of public funds for projects whose outcomes are inherently uncertain. Dr. Kelly pointed to the Academy's recent publication *Evaluating Federal Research Programs* as a thoughtful examination of the issue. Plainly, you do not want to hand out public money without accountability, but specifying an evaluation program to ensure accountability when research outcomes are uncertain is a difficult task. Dr. Kelly noted that, in the Academy's study, a problem in the evaluation of basic research was identified: If you set the objectives too narrowly, you wind up characterizing an outcome very conservatively. That is, the evaluation criteria discourage the risk taking that the R&D program is supposed to foster. Dr. Kelly said that society must be prepared to tolerate some failure in R&D programs.

In concluding, Dr. Kelly said that the panelists could provide "the gift of common sense" in providing their perspectives on how the ATP has operated and adapted to change over the past 10 years.

DECISION MAKING: THE ATP SELECTION PROCESS

Lura Powell
Advanced Technology Program/
National Institute of Standards and Technology

I am pleased to be here today to review the Advanced Technology Program. It is an exciting time for ATP—we are entering our tenth year and can say with confidence that the program is making a difference. Today, as you will hear in the following panels, we have significant evidence and real-world success stories to show this.

This symposium here at the Academy is the perfect forum for discussing both the program's accomplishments and the challenges that lie ahead. I am looking forward to hearing the perspectives offered by all of today's participants and learning how we can improve the ATP as it enters its second decade.

Today I want to share briefly some interesting facts about the program as well as our selection criteria and process. I also want to spend a few minutes, at the end of my talk, highlighting some of our successes.

Competitive Landscape and the Need for Government–Industry Partnerships

Let me start by reminding us all of why we have the program. The ATP was created to foster economic growth through the development of innovative technologies. As you know, advanced technology drives U.S. leadership in the global economy, accounting for over 50 percent of U.S. economic growth in the postwar era. Continued innovation in U.S. industry is crucial to sustaining our global competitiveness, and these technical innovations depend upon continued investment in long-term, high-risk research today.

Unfortunately, private industry has been reluctant to fully fund this critical type of high-risk, enabling research. The reasons for this underinvestment are complex, but three explanations stand out: First, benefits from these long-term, high-risk innovations often are dispersed too widely for any one company to recover its investment at a sufficient profit. Second, global competition has forced industry to focus on bringing products to market rapidly. Third, many R&D challenges are so large or complex that no single company has the resources to address them alone.

By stimulating industry investment in innovative technology with the potential for broad national benefit, government–industry partnerships, such as the ATP, address these sources of market failure.

The ATP Selection Process

I would argue that ATP's early-stage investment is accelerating the development of high-risk, broadly enabling technologies, helping to bridge the gap between the laboratory and the marketplace. Further, I believe that the program has been successful because we leverage private-sector resources through cost-shared R&D partnerships that promote competitive advantage while delivering major national benefits.

ATP projects are submitted by industry and undergo a rigorous, peer-reviewed competition before they are selected. Although the ATP funds all areas of technology, there is a special niche of technology projects that the ATP looks for. In the process of assessing each proposal, the ATP examines the innovations in the technology, the degree of technical risk, the feasibility, the quality of the R&D plan, pathways to economic benefits, and the need for ATP funding.

Each proposal is evaluated by a selection board, comprising both technical and business experts. The selection board examines the scientific and technological merit of the proposal as well as its potential for broad-based economic benefits. The selection criteria are weighted equally between technology and economics, and within each there are "must have" elements that a proposal must address.

To meet our technology criteria, a proposal must show that the proposed technology is innovative and currently faces high-risk technical barriers that, in light of current knowledge, possibly can be overcome. The proposal also must lay out a research plan that is credible, detailed, and includes measurable milestones. Last but not least, the proposal must show how the project will contribute to the U.S. technology knowledge base.

On the economic side, the proposal must demonstrate the technology's potential for broad-based economic benefits, explain why ATP funding is necessary, and tell what difference ATP involvement is expected to make. Although commercialization, which is paid for by the company, occurs after ATP-funded R&D, a successful proposal must have a strong commercialization plan that demonstrates the potential for benefits beyond profits to the company. Successful commercialization of the technology is what links the R&D and the economic benefits.

Questions have been raised as to whether ATP awards replace private capital. This is not the case—the ATP selection criteria are very different from those applied by the venture capital community. The venture capital community focuses on capturing the private benefits that go to the innovating company. The ATP looks for the broader perspective—selecting projects that have the potential for broad-based economic benefits, not just direct benefits to a single company. If a proposal addresses path-changing technology, has potential for broad economic benefit beyond the innovator, and shows good evidence of a strong need for ATP funding, it is a good candidate for an ATP award.

ATP Is Making a Difference

As alluded to in my opening comments, we are accumulating a wealth of successes associated with our funded projects that show that the program is making a difference. Many of our earliest projects are now commercializing products and realizing benefits. This is providing the program with the opportunity to examine critically the impact of those projects. In fact, as Ray Kammer announced earlier, we have just completed an analysis of the first 38 completed projects.

As you might expect, out of those first 38 awards, not every project has been a smashing success. We have a handful of projects that would be considered hugely successful, a portion that must be designated failures, and a large group that are on the road to commercialization, but whose impact on the economy remains to be seen. We have had our share of R&D investments that did not deliver, of economic reverses, and of sudden changes in direction on the part of our private-sector partners. In my view, we are about where we ought to be, that is, out toward the higher-risk end of the spectrum, encouraging industry to take on the tough challenges, with potentially broad-based benefits. However, it is clear already that the expected benefits from these projects far exceed their total costs.

If we look across our entire portfolio of projects, some interesting facts emerge that underscore the value of the ATP and its contribution to the R&D enterprise. First, the ATP has been responsible for accelerating R&D and reducing the time to market. Second, our awardees have identified 37 percent of ATP technologies as "new-to-the-world" innovations. Third, ATP projects have identified 1,200 potential applications (an average of 4.5 per project) and produced over 100 new technologies that are now being commercialized as products, processes, or services. Fourth, we see substantial job growth in our companies—in the first 38 projects, almost all of the small, single-applicant companies have at least doubled in size since they received their initial ATP award.

To give you a flavor of the technical successes we are having, consider the following examples: Two small companies are developing miniaturized DNA analyzers that are greatly increasing the speed of research and medical testing for diseases such as HIV, strep infections, or cancer. Another small company improved the properties of carbon- and glass-reinforced polymer composites to design and manufacture bridge beams that are expected to outlast conventional steel and concrete. And, six top U.S. printed-wiring-board suppliers and users teamed to achieve literally dozens of technical advances that have been credited by the National Center for Manufacturing Sciences with saving the U.S. printed-wiring-board industry with its 200,000 jobs.

By stimulating collaboration and investment in high-risk, path-changing, and broadly enabling R&D, the ATP is changing the nature of the R&D projects that companies undertake and encouraging the development of new technologies that will underpin U.S. economic growth in the next century. Thank you.

MISSION SYNERGIES

Jeffrey Schloss
National Human Genome Research Institute
National Institutes of Health

I am here on behalf of Dr. Francis Collins, Director of the National Human Genome Research Institute (NHGRI) of the National Institutes of Health (NIH). Dr. Collins sends his best regards, and asked me to convey his regrets that his travel schedule precluded his participation in this important discussion. Dr. Collins also asked me to convey that successful achievement of the ambitious goals of the Human Genome Project (HGP) can be accomplished only by an effective partnership between the publicly funded effort and private enterprise. Development of new technologies is a particularly fertile area for such partnership efforts, and we have been delighted to work closely with NIST's Advanced Technology Program to help develop DNA Tools**.** This program has advanced several areas of technology, especially microelectromechanical systems, in ways that should substantially benefit the public over the long term.

Before I proceed with these remarks, let me say that I am well aware that the ATP addresses an array of goals and that commercialization of DNA and genomics tools is just part of that broader program. However, to focus my remarks on issues directly related to the Human Genome Institute, I will limit them to this area of the ATP, and you can decide whether our perspective has its parallels in other sectors.

The Human Genome Project

The Human Genome Project has been overwhelmingly successful in producing and bringing into the public domain vast amounts of data about the human genome and the genomes of several other organisms. It also is changing the way that biomedical research is done. Let me use positional cloning as an example. In these experiments, family members of individuals with hereditary diseases are studied in order to locate the genes responsible for their ailments. Just a few years ago, these experiments took tens of people several years of work. As a result of the human genetic and physical maps generated by the HGP, it has become possible for a small laboratory to map the susceptibility gene for Parkinson's disease in just nine days, and identify the specific mutation in just a few months.

Similarly, DNA sequence data from model organisms and from expressed human sequences, produced through the efforts of the Human Genome Project and its partners, have dramatically accelerated our ability to understand the role of these genes in cells and in disease. These are just examples of some of the most obvious results of having available genome-wide data. In fact, using genomic data, it is now possible, and will become increasingly practical, for a wide variety of experiments to be designed in new and different ways, and potentially to be performed much more quickly and accurately, than would have been the case before genome data had been collected and genome approaches had been conceived.

Developing New Tools for Genome Research

To realize this potential, new lab methods and techniques need to be developed. NHGRI and other components of the NIH are actively supporting research to develop these new technologies. For example, we supported many of the initial studies from which have resulted the development of two major ”flavors” of DNA array technology, sometimes known as “gene chips.” These technologies can be used to assay changes in gene expression between different stages of embryonic development, in different kinds of tissue such as muscle or skin, in healthy or diseased tissue, and before and after drug treatment, to name just a few examples.

Similarly, these chips can be used to rapidly screen for alleles of known mutations. This information in turn can be used to aid in gene discovery, to determine a patient’s susceptibility to particular diseases, or to determine if a patient will likely respond to a particular drug or have an adverse reaction to a drug. We also are supporting technology research to understand the fundamentals of how to miniaturize important biological assays—such as polymerase chain reactions and DNA size separations—and accomplish them on microfabricated devices. Additional research is proceeding on how to integrate multiple assay steps on single devices so that many samples can be analyzed in parallel, and sequentially, to achieve the high-throughput, cost-effective capabilities that are needed to take full advantage of genomic data.

Research Challenges for Genome Research

This is indeed an exciting time. However, there are stumbling blocks that could hinder the achievement of this vision:

- *Multiple Technologies:* There are a number of different technologies that must be developed to achieve all of these goals. It is not clear at present which of them will be optimal for which assays. Some of the uncertainty lies at the level of basic science, some uncertainty is derived from operating the technology at large scale, and some emerges at the level of commercialization. If we only explore those technologies that appear to be most promising in the near term, we may forfeit the potential to realize the truly novel approaches that are just beyond the horizon.

- *Technological Complexity:* These are very complex technologies to develop. Many of them require state-of-the-art analytical chemistry and molecular biology to be integrated with microfabrication, optics, and electronics. And, for the information they produce to be useful, their development has to be coupled with sophisticated mathematical and bioinformatic tools. This complexity and need for multidisciplinary participation increases the development costs and risks. I participated in a discussion recently in which a chemist and an engineer were discussing one of these projects. The engineer described a complex sequence of development benchmarks and concluded that the project was challenging, but was the sort of thing that his team had accomplished successfully in several previous projects. The chemist pointed out that those projects had all involved sophisticated electronic, optical, mechanical, and software engineering, but that this one added analytical chemistry. The engineer was silent for a moment and agreed that this factor added a completely new level of complexity.
- *Higher Costs:* The result of this complexity is that each of the technologies, and therefore the sum of the technologies, is expensive to develop. Conservative estimates by our advisors state that the development phase for these technologies costs at least 10 times as much as the initial research to show proof of principle. So, it is clearly beyond NIH's ability alone to fully develop these promising technologies.

Synergies Between ATP and NIH

NIH investments tend to be more toward generating and demonstrating new research ideas. However, the ATP is able to focus on stimulating specific sectors where there is particular potential to drive these new ideas toward realization as products that can be put in the hands of a much wider group of users, through commercialization. The ATP's choice of DNA Tools is an excellent example of selecting an area where the risks are such that, for reasons outlined above, investment by the private sector may be insufficient to fully realize the potential in a timeframe that would optimally deliver the technology. The result of ATP investment in DNA and genomics technologies has been to stimulate this sector, in order that a much wider array of ideas can much more rapidly be converted into methods, devices, and reagents that actually work.

By stimulating a sector such as this, multiple begin companies working in competition, but also stimulate each other to produce these products more quickly. In addition, because a number of different approaches have the opportunity to develop, the market is much more likely to receive products that have the desired specificity and sensitivity. This might not occur if only a small number of technologies that appear to have the very highest chance of success, and therefore garner the limited amount of private funding that is available, were allowed to develop.

Another advantage of running a program such as this in cooperation with the ATP, is that NIST already has experience with a wider range of cutting-edge technologies than does the NIH. For example, the synergies that can develop between microfabrication methods that have been developed for the electronics industry and that are showing such great potential when applied to miniaturized, high-throughput assays for genomics, may be better leveraged by an agency that has more experience interacting across these industries. This is not to say that NIH cannot partner with other agencies to develop such programs. But it is a good thing to take advantage of the variety of missions, perspectives, and experience that exist in our federal agencies, to support research and development in areas that are acknowledged to be of great importance.

My discussion of the potential for partnership between agencies prompts me to make clear that this actually is happening. For example, staff of NHGRI have for the past several years been in active and frequent contact with staff of relevant programs in other agencies such as the Defense Advanced Research Projects Agency, the ATP, as well as the National Science Foundation. This helps staff to maintain awareness of each others' programs and to contribute when appropriate.

In closing, I want to underscore that ATP activity in the area of DNA technologies has and will benefit not only the diagnostics communities, but also our programs at NIH, in important ways. First, the value of Genome Project products increases because more people will gain access to the tools that allow them to take advantage of those products. Also, as the companies that are developing these products gain experience and build their infrastructure, they can turn part of their attention to solving the problems that will allow our grantees to extract from biological systems the next generation of genomic data. Thus, just as the ATP leverages research supported by other agencies, those other agencies now can leverage of ATP investments. This continues to build strong synergy between agencies and advances all of our missions. I appreciate the opportunity to make these comments regarding the Advanced Technology Program. I would be pleased to answer questions that would clarify any of these points.

INDUSTRY PERSPECTIVES I

David Gibson
X-Ray Optical Systems, Inc.

Mr. Gibson said that he would try to offer a practical perspective on what the ATP has meant to his company and draw the attention toward program operation and away from what someone had called the "religious discussion" about the program. Mr. Gibson began by describing his company's technology as a means to better convey how the ATP grant helped X-Ray Optical Systems.

X-Ray Optical System's Technology

The technology that his company proposed to the ATP was designed to make optics that control x-rays. At the time that the technology was proposed, there existed no lenses that were able to control x-rays. Today, his company can make parallel beams and convergent beams, the applications of which are primarily in analytical instruments that allow users to understand the composition or the crystalline structure of a material. These techniques are used extensively in high-technology industries, especially semiconductors and pharmaceuticals, and for turbine blades. Other applications are found in the steel and construction industries in the analysis of steel or cement integrity.

X-Ray Optical Systems was founded in 1990 on the basis of a technology whose basic research had been conducted in the former Soviet Union. At that point, there had never been an optic such as X-Ray Optical's manufactured in the United States; indeed, given the Soviet origins of the research, such an optical had never been in the United States. The company applied for ATP funding in 1990 and was turned down. This was appropriate, because X-Ray Optical had not done enough to convince ATP reviewers that the company had the team or business plan to develop the technology successfully.

In 1991, the company submitted another application to the ATP and won an award in early 1992. X-Ray Optical had only two employees when it applied for the ATP grant, and only three when it received the grant. At the time the grant was given, the Soviet optics technology had been demonstrated as viable, but the technology had no practical uses. Although the technology developers believed that the technology had commercial potential, there were scientists who disagreed with that assessment. Some scientists thought the technology had practical application only in theory; none believed that theory could be reduced to practice.

The ATP was capable of making its own judgment on the technology's practical and commercial potential and thought the technology was a risk worth pursuing. Today, X-Ray Optical Systems makes the optics it promised in wavelengths that are useful. The company has advanced to the point where it works with the "lead end user," such as academic and government scientists, as well as equipment manufacturers to install the optics. In the past year, the company has had its two equipment manufacturers sign contracts for volume orders, which moves the company away from "one off" products for specific users. The company currently has seven U.S. patents, as well as patents pending in 15 countries. X-Ray Optical Systems is, said Mr. Gibson, the world leader in the technology.

However, there is a long lead-time to introduction. Once the company demonstrates the technology and its value in an application, there is typically a three-to five-year lag until the optic finds its way into use. An optic provides no value in itself; a host of other things, such as the proper x-ray source and software, must be developed before users can integrate it into a system. His company is at that point today, Mr. Gibson said, and it is also profitable.

Role of the ATP in X-Ray Optical's Development

At the outset, Mr. Gibson said that his firm searched for private financing for the company but was unable to procure any that would allow X-Ray Optical to be independent and to operate in the United States. Specifically, the company started with personal funding. As with most high-technology start-ups, the principals emptied bank accounts, cashed in liquid assets, sold the house, borrowed money from friends and parents, and even dipped into parents' pension funds. You have to "dig pretty deep" and these sources of funds were used up by the time the company received its ATP funds. The personal sources of funds came to $300,000 to $400,000.

Loans were out of the question because they are based on assets, and the company had none that a bank could use as collateral. X-Ray Optical explored venture capital funding but, Mr. Gibson said, venture capitalists have a difficult time providing funds to young companies that have high technical risk. Venture capitalists also could see that they or the company were unlikely to capture the full benefit from X-Ray Optical's technology.

The company looked to private sources of funds, which is generally a good avenue to pursue. However, private sources, that is, individual wealthy "angel" investors, usually find it hard to assess highly technical risks such as the one that X-Ray Optical Systems presented. Such private investors typically would turn to scientists but, as Mr. Gibson had mentioned before, many scientists had concerns about his company's technology. Other government policy measures, such as R&D tax credits were simply irrelevant to his company; tax credits provide no cash and they are useful only if a firm is profitable, something X-Ray Optical knew was not going to happen for several years.

As for an initial public offering, that was not an option for a risky technology that was not going to yield a product for a number of years. Finally, strategic partnerships were explored, and X-Ray Optical System's principals had anticipated this to be an attractive source of funding prior to applying to the ATP. However, the company's risky technology and long lead time until a product was likely to be ready for the market caused potential partners to undervalue the technology.

In the end, it appeared that selling the technology to Japanese investors was going to be the only option. This was not something the management of X-Ray Optical Systems wanted to do. However, the company was able to turn to the ATP for funds, and this allowed X-Ray Optical Systems to remain based in the United States. With ATP funding in hand, the company was able to bring in private funding from angel investors. These investors had committed to fund the company if the technology passed NIST's technical evaluation in the ATP grant process and the company was successful in obtaining an ATP grant.

Today, X-Ray Optical Systems is at a stage where it can reasonably expect to gain additional funds from a venture capitalist. The company is looking at various options for procuring financing from venture capitalists. With respect to matching funds, Mr. Gibson said that government reporting requirements substantially understate the amount that private firms contribute. The government asks for information only on the amount of the matching funding during the time horizon of the ATP grants. This misses the resources contributed by private investors before the ATP grant and afterward.

ATP's Contribution to the Economy

One of the reasons that it is hard to obtain funding for a technology such as X-Ray Optical System's is that the firm captures only a small portion of the value it creates. An economist would say that X-Ray Optical creates spillovers or externalities as it develops technology. His company manufacturers an optic, which then is put into a system; the system then goes to a customer who is a manufacturer that uses the system to investigate the properties of a component it sells. The component is purchased by an end user. The optic's economic value as a fraction of total value declines along this chain; an optic sells for tens of thousands of dollars, and is used in a system that may sell for $250,000. That system is sold to a manufacturer who uses it, for example, to improve production yields whose value may be in the millions of dollars. For a single optic, X-Ray Optical System captures less than 1 percent of the total value that the optic creates. This is not a social good, Mr. Gibson pointed out; it is a private good for others, but not for X-Ray Optical Systems.

ATP Funding Versus Other Government Sources

Another helpful dimension that NIST brings to the ATP is its technical capabilities, Mr. Gibson said. The company used three different labs at NIST, and when a technical hurdle was encountered, the company was able to look to a variety of technical resources at NIST for advice. Without NIST's technical assistance, Mr. Gibson was unsure whether his firm would have been able to turn a profit. Although NIST's technical assistance would have been available without the ATP, Mr. Gibson said that he probably would not have turned to NIST in the absence of the ATP.

In summary, Mr. Gibson said ATP funds made his company possible. Because the ATP allowed his company to remain in the control of U.S. investors, the United States went from not being a player in the field of x-ray optics to being the world leader. The return to the economy from ATP funds is many times the amount of the ATP grant. Finally, the technical resources at NIST were invaluable and helped to help the company grow.

INDUSTRY PERSPECTIVES II

Richard Ramseyer
Honeywell Technology Center

Mr. Ramseyer observed that he was one of the few participants in the discussion from a large corporation. Accordingly, he thought it would be useful to provide the perspective of a large high-technology corporation. He noted that one of the mantras of the Chairman of the Board of his company is: "Never take a profit tomorrow that you can take today." One might think that this flies in the face of making investments in long-term R&D, even when the cost is reduced via a program such as the ATP. At his company, however, it is the task of the Honeywell Technology Center to look beyond the existing business units to anticipate technology needs 3 to 10 years into the future. When a Honeywell business unit wants to move swiftly into a new market, the Technology Center is there to ensure that the company has the technological capability to do so.

The ATP and Honeywell

The Honeywell Technology Center uses the ATP as part of its strategy to scan the horizon for new technological opportunities. Mr. Ramseyer recalled the earlier so-called "religious discussion" of about whether the program should be funded at all or whether $200 million was the appropriate funding level. Whatever the merit of that discussion, Mr. Ramseyer said that it was important to look at the results of the ATP. It is important to "keep our eye on the ball" when talking about the ATP and, in his view, the taxpayer has been the real winner with the program.

Mr. Ramseyer said that, even though an ATP grant of $2 million was an attractive prospect for a company, there are hidden costs to companies that participate in the program. It may cost half of a $2 million grant for a company to form and operate a consortium for an ATP grant, which often is the only way to undertake a sizeable ATP project. This suggests that there are reasons other than the award for being involved.

Examples of ATP's Benefits to Honeywell

One example of an ATP partnership for Honeywell is one in which Honeywell, SEMATECH, Advanced Micro Devices (AMD), and NIST collaborated on the Advanced Process Control Framework. Many in the computing and electronics industry are aware of Moore's law in which Intel cofounder Gordon Moore predicted that the number of transistors on an integrated circuit would double every 18 months; this has faithfully been the case over the past 30 years. Mr. Ramseyer raised what he called "Moore's lament" whereby the cost of fabrication facilities increases exponentially and the cycle time to build new semiconductor chips is growing longer. The Advanced Control Process Framework, funded by the ATP, has been an attempt to address these rapidly escalating costs. The framework has started to yield some successes: for example, AMD reported savings of $10 million in fabrication costs due to the ATP-funded initiative.

The software that supports this initiative has been installed at other semiconductor firms, and the software is now a commercial product sold by a company named Quantum Space. Mr. Ramseyer noted that AMD's K6 processor is much cheaper than its Intel competition, which results in less expensive personal computers for consumers.

Another ATP success for Honeywell from its participation in ATP is in Abnormal Situation Management. One of Honeywell's largest customers is the hydrocarbon business; 85 percent of the world's gasoline is refined using Honeywell controls. Honeywell is therefore always looking for ways to make refineries run more efficiently. A pervasive problem in the refinery industry is panic among operators when an alarm in the refinery is sounded. It is understandable, given the consequences of so-called "refinery upset," that operators tend to shut down the refinery completely until the problem is found. Because it is expensive to restart a refinery once it is shut down, the cost of these decisions are substantial—as much as $20 billion annually in the industry.

Working with the ATP, Honeywell signed on every major refiner in the world to develop a system that would distinguish between problems that warrant a complete shutdown and problems that could be addressed without a costly shutdown. The system is proving to be effective and, Mr. Ramseyer added, will have applications in other industries. Chemical and paper plants will likely benefit, as well as airports.

For the future, technologies for the elderly will take on greater importance. It costs the economy approximately $100 billion per year to care for the elderly in nursing homes or hospitals. Information technology can improve the efficiency and quality of health care delivery to the elderly and generate substantial savings.

For Honeywell, each of the ATP projects in which it participated involved a great deal of technical risk. Each member of the consortium may have a piece of the solution, and may be confident that a solution is out there, but what the solution is and how it fits together is uncertain at the outset. In sum, Mr. Ramseyer said that, in Honeywell's experience, the ATP has stimulated innovation and commercialization of products to the benefit of a broad range of companies and the taxpayer.

DISCUSSANTS

William Newall
Axys Pharmaceuticals, Inc.

Mr. Newall began his remarks by saying that Axys Pharmaceuticals has been a recipient of the ATP awards in the past, giving the company some perspective on how the ATP functions. Axys has found the ATP to be a valuable program and, even though Axys received its grant only last fall, the company believes that the program is meeting the objectives set forth in the legislation.

Axys and the ATP

Axys Pharmaceuticals is a biotechnology company that qualifies as a small business; its primary corporate mission is to discover and develop small-molecule therapeutics that can be taken orally to treat diseases. To do this, Axys uses a variety of extremely sophisticated technologies, one of which is microray technology. This technology is a tool used in the biotechnology business, and Axys normally would not develop it. Indeed, when faced with a "make versus buy" decision on such a technology, Axys normally would buy it. However, an Axys scientist came up with a revolutionary microray technology called "liquid arrays." This allows companies such as Axys to develop drugs of higher quality and in a less expensive and more timely way.

As a small company with limited resources, development of such a tool ordinarily would not be a priority for Axys. The company's main business thrust is in discovery of new drugs, and the technology, although exciting, was too speculative in nature, too expensive for Axys to pursue by itself, and too tangential to its core business. With the widespread pullback of the U.S. venture capital community from the biotechnology industry, Axys knew it would be very difficult to obtain the financing to bring the technology to fruition.

Without the ATP, Axys would have put this idea on the shelf and would not have pursued it. As a counterpoint to some of Claude Barfield's comments, Axys would not have moved forward with this technology development without the right to keep and commercialize the intellectual property rights created in the program. There would not have been the financial returns that Axys investors require without the right to retain the intellectual property created with the ATP grant.

Observations on the Operations of ATP

The fact that there are no funding caps placed on ATP grants is a valuable attribute of the program, Mr. Newall said, adding that this stands in contrast to the caps in the Small Business Innovation Research (SBIR) program that do not allow for multimillion dollar development projects. SBIR grants are useful, and Axys has benefited from them, but many new technologies, such as liquid arrays, are very expensive. The size of ATP grants permits such technologies to be developed fully, not just gotten off the ground.

The cost-sharing feature of the ATP is a reasonable balance of risk between government and industry. Because a company will benefit from technology developed under the ATP, it is entirely appropriate that the company bear the risk. Putting a company's own funds at risk is a good way to ensure a company's commitment to completing technology development and commercializing. When companies have their own resources at risk, Mr. Newall said, they have incentive to work harder.

Axys believes that an ATP grant is an important validation of new technology ideas, especially for high-risk enabling technologies. In addition to the technical risks, there is significant commercial risk in developing new technologies. Between these two kinds of risks, technology development is a high-stakes game, especially for small companies. However, the ATP process helps to lessen these risks because of the rigorous technical and business reviews that are part of the application process. The process means that ATP award recipients have had their technologies and business plans vetted by experts. Not all risk is removed through the process, of course, but companies take greater comfort in pursuing the technology given the technical and commercial review that goes with winning an ATP grant. To a manager trying to make a decision, the external validation provided by the ATP can make the difference between a "go or no-go decision."

Suggestions for the Improvement

Axys believes that the ATP application and timeline can be streamlined. Mr. Newall said that he did not want to overstate the point, because Axys received its ATP funding nine months after initiating the grant application process. Nonetheless, Axys believes that a review of the information requirements for the application would help to accelerate the decision-making process within the program. Particularly for small businesses, Mr. Newall said, the scope and detail of the information required in the application can be daunting.

Axys also would like to see parity given to applications from single companies as compared to applications from joint ventures or consortia. Under the current ATP rules, a single company cannot obtain financing for indirect costs associated with the projects; joint ventures can. Because indirect costs can run as high as 70 percent of total costs, there is substantial disincentive for individual companies to apply to the ATP. The program does not take into account whether companies have "contractual rather than equity partners."

In addition, there is a funding limit of $2 million over three years that does not apply to joint ventures. Axys believes that this provision should be reviewed. From his own experience, Mr. Newall said that he understood joint ventures to be challenging; some work well, others fail. When joint ventures fall apart, Axys believes that there are problems inherent in the ATP grant-making process that may make it difficult for the project to move forward should the partnership dissolve.

In the case of liquid arrays, Axys ordinarily would not have moved forward with the technology through a joint venture, but rather through a contractual arrangement with another company. In most cases, Mr. Newall said, a small company probably would develop a technology jointly with another firm, even though the relationship may not be as formal as a consortium or joint venture. It is contractual partnering that allows the ATP's goals to be met. For example, if a single company takes the lead in development and forms contractual relationships with other companies to further the development process, it may make sense to allow the lead company to substitute another company in the development chain if one of the original firms fails to hold up its part of the development bargain. If ATP's rules preclude this kind of substitution, necessary flexibility among firms is constrained.

In closing, Mr. Newall said that Axys believes that ATP represents a successful partnership between government and business. It provides a successful financial bridge to encourage the development of new technologies. By focusing on enabling technologies, the ATP leverages the government's investment many times, creating an economic ripple effect that creates more U.S. jobs and aids in keeping the United States the world leader in technology.

Jeff Grove
House Committee on Science

Mr. Grove noted that he has just assumed the position of staff director of the House Committee on Science's Subcommittee on Technology and, as such, is benefiting from hearing the views of large and small business on the ATP. On the basis of his experience with the program, Mr. Grove said it was clear that grant recipients are pleased with the program and have received benefits. He noted that auditors and research done by several think tanks have raised questions about implementation of the program.

For Congress, Mr. Grove said, there would be a clear benefit from hearing recommendations such as those from Mr. Newall on streamlining the application process. The debate over funding and scope of the program are largely off the table in that those questions would be settled on the basis of the overall budget for science and technology programs.

Given his desire to learn more about the ATP, Mr. Grove said that his time might be better used by asking some questions. In that light, he asked Dr. Powell to comment on Mr. Newall's suggestions for improving ATP.

In response, Dr. Powell said that ATP has made a number of efforts over the years to streamline the program through outreach to ATP grant winners and non-winners. It is an issue very much in ATP's sights, and Dr. Powell said that she would discuss in detail with Mr. Newall his suggestions. With respect to Mr. Newall's comments on the treatment of single-company applicants versus consortia, Dr. Powell said that this is another area for improvement that ATP is studying. This would require legislative changes to ATP's statute. Given that, Dr. Powell would welcome additional input from industry, as well as dialogue with legislators.

QUESTIONS FROM THE AUDIENCE

Dr. William Long of Business Performance Research Associates commented on the ATP projects of Axys and X-Ray Optical Systems based on information from the ATP Web site. The difference between the joint venture and the single-applicant approach showed up in only one place, Dr. Long said, and that is funding. There is a cap on the single applicant and not on the joint venture. Dr. Long did say that there appeared to be a lack of parity in treatment of joint ventures versus single applicants. He asked panelists to comment on the differences in making grants to single applicants versus joint ventures.

Mr. Newall said that when Axys first considered the ATP for funding of its liquid-array technology, it quickly realized that it could not develop the technology on the $2 million limit imposed by the ATP on a single applicant. So, Axys did look for a partner to apply for the grant, and partnered with Luminex, in what has been a mutually beneficial arrangement. In effect, ATP rules required that Axys find a partner if the company was to pursue the liquid-array technology. If the necessary funds—on the order of $7 million to $8 million—had been available to Axys as a single company, Axys would have structured its application differently. Axys likely would have applied by itself to the ATP and entered into a subcontracting relationship with its partner.

Mr. Gibson from X-Ray Optical Systems said that his company also considered the joint venture versus single-applicant issue. When his company applied for its second round of ATP funds, the company knew that about 2.5 percent of single-company applicants that applied received funds, whereas that figure for joint venture applicants was approximately 12 percent. When X-Ray Optical gave its oral presentation to the ATP, a point in the application process at which roughly half the companies invited to give such presentations win funding, the company said that it was willing to go forward knowing that its chances of winning the award were lower as a single applicant. First, the $2 million funding cap was not a problem for X-Ray Optical Systems; that was sufficient funding for the project. Second, even though X-Ray Optical Systems had excellent relationships with university researchers and several other companies, it believed that structuring its application as a joint venture would impose burdens that would lower the probability of a successful technical outcome.

Flexibility was the driver behind the decision against pursuing a joint venture. If a partner proved incapable of fulfilling its role, Mr. Gibson 's company believed that it would be better able to jettison the partner and find a new one if X-Ray Optical Systems were the sole recipient of the ATP grant. It is possible to restructure participants in an ATP grant with a joint venture, but there are some costs. In summary, Mr. Gibson said that his company was willing to accept a lower probability of winning the award as a single-company applicant, because the company believed that it had a higher chance of technical and commercial success applying as a single company. The bias in the legislation toward encouraging collaboration among companies in the application process is well-intended, in that it is essential to have multiple skills from multiple organizations to be successful. However, the organizational bias toward the joint venture, reflected in the administration of ATP is a "very poor" way to accomplish this goal.

Jon Baron, manager of the SBIR program in the Department of Defense, asked for an elaboration on how the ATP evaluates the commercial or spillover potential of applicants. Dr. Powell responded by saying that the ATP has a peer review process on the technical and business side for applications. The ATP gathers experts from the world of business and economics, as well as technologists, to scrutinize proposals. It is not difficult to find qualified technologists, but the ATP does face a scarcity of expertise among economists and business people. Often, therefore, the ATP draws on retired business people and the best available academicians to review business plans. The ATP also makes sure that its outside experts have no conflicts of interest because the review process involves the disclosure of proprietary information.

Mr. Baron followed up by asking the two panelists from industry what they thought of the process. Mr. Gibson said that, when his company was turned down the first time, the ATP was "right on the money" because X-Ray Optical System's business plan was not well developed at that point. Mr. Gibson said that the oral presentation to the ATP panel and subsequent questions from panelists were of excellent quality and certainly found holes in X-Ray Optical's proposals where holes existed. The review panel was extremely well prepared and knew what it was doing.

Panel III:
Research Perspectives on the ATP

INTRODUCTION

Richard Nelson
Columbia University

Dr. Nelson introduced the panel with a number of observations that he hoped would frame the discussion on research perspectives on the Advanced Technology Program (ATP). Dr. Nelson said that he found Dr. Hill's earlier remarks on the history of the ATP to be fascinating and consistent with his understanding of the ATP's origins. One thing that the ATP's history demonstrates is that the program did not enjoy widespread support when its authorizing legislation was passed. The question of the program's objectives and instruments was left "quite vague and loose." Dr. Nelson said that those who were charged with implementing the program had "to make a silk purse out of a sow's ear." The ATP has been blessed by having a number of intelligent and dedicated people working to create a first-rate program. This has been challenging, given the broad mandate of the ATP and the constraints imposed upon it since its inception.

From the beginning, the ATP has had to struggle with two broad questions:

- What has the program tried to achieve? As Dr. Hill's remarks demonstrated, many different actors have had different perspectives on what the program was trying to do.
- Given vaguely defined objectives, what procedures should be implemented to award grants?

Both questions should be kept in mind when thinking about how best to assess the ATP. As we look at how the ATP addresses these and other issues, it is important to view the ATP's actions as "compared to what?" We may want to view the ATP as one of a number of other programs that might loosely comprise a national technology policy. Then we may ask whether the ATP is an important part of a technology policy or whether there are other objectives in the technology arena that the ATP may not address effectively. For example, Bill Spencer and others have written about the decline of large corporate industrial research laboratories, particularly in electronics. Is the ATP a vehicle to address that problem? If so, is the ATP better than an alternative approach?

Dr. Nelson also noted that several speakers had mentioned that the ATP has changed over the years. He hoped to hear in this panel's discussion more about how the ATP has changed. The ATP is a program with boundary conditions set on what it can do, but a lot of room to maneuver within those boundary conditions. Comparing the ATP to SEMATECH, Dr. Nelson recalled that the SEMATECH consortium began its life with one set of objectives and design and changed dramatically over the years; eventually, it found a niche different from the initial intent. With respect to the ATP, Dr. Nelson said that the ATP should be evaluated with an aim toward refining and fine-tuning the program so that it can adapt appropriately to changing circumstances.

Commenting on Dr. Powell's remarks, he noted that she said that he ATP has, over time, placed a greater emphasis on creating spillovers through ATP grants as opposed to fostering commercialization. Dr. Nelson said that this seemed to be a plausible shift. However, Mr. Newall's statements in the prior session caused Dr. Nelson to pause, because Mr. Newall's comments suggested that ATP grants were oriented to company-specific benefits. This indicates a "tension and schizophrenia" in the program that has been an ongoing struggle for the ATP. Dr. Nelson hoped that today's panel could address this last issue, among many others.

ASSESSMENT OF THE ATP

Rosalie Ruegg
National Institute of Standards and Technology

An Early Start at Program Assessment

As the National Institute of Standards and Technology's (NIST's) Director Ray Kammer mentioned, the ATP initiated evaluation from the beginning of the program and well before the passage of the Government Performance and Results Act (GPRA). With NIST's long history of measurement, it has been a good home in which to develop performance metrics for the ATP. Not surprisingly, the physical scientists in the NIST laboratories sometimes look a bit askance at social scientists as they see the many assumptions that must be made in estimating effects within complex economic systems. The projections that go hand in hand with estimating time-dependent effects, and the rounding to millions of dollars seem strange to those who measure physical phenomena to the fifteenth decimal place and beyond. However, both share a passionate interest in measurement, and NIST is an excellent place for measurement of all kinds.

A System of Continuous Improvement

An evaluation effort for the program was put into place for two reasons: first, as a management tool, to meet program goals and to improve program effectiveness; and, second, to meet the many external requests for ATP program results, requests that seemed to arrive fifteen minutes after the program was started. Still, this early start in assessment was a help to us later in meeting the GPRA requirements, as well as to prepare an initial report to Congress on progress.[1]

Evaluation is most potent when it is integrated into program management. To maximize effectiveness, we believe that program management must have four elements:

- Design
- Implementation
- Assessment
- Learning and Feedback

It is important to note the sequence that begins with program design and is followed by implementation, assessment, lessons learned, and feedback. However, this is not simply a linear sequence, but a cycle in which assessment, lessons learned, and feedback would be reflected in appropriate modifications to program design, implementation, and so on. Our goal is to have program evaluation fully integrated into the program's dynamic structure and contribute to continuous program improvement. This goal is being realized.

Not surprisingly, this achievement has not happened overnight. First, we had to develop the evaluation program and put it into practice. Then we had to track projects, compile data, perform analyses, and begin deriving lessons from the early results. Now we are gaining insights into what aspects of the program are working and what is not, and this information is providing a basis for program modifications to improve effectiveness.

As an early example, we found that some of the joint ventures that were announced as award recipients never actually got off the ground—principally because the members were unable to reach an agreement among themselves on the terms of their collaboration. We learned that joint venture formation was more difficult than we had expected at the outset of the program.

---

[1] National Institutes of Standards, *The Advanced Technology Program: A Progress Report on the Impacts of an Industry–Government Technology Partnership*, Washington, DC: U.S. Government Printing Office, 1996.

Termination and Alliance Networks

As of the beginning of March 1999, roughly 6 percent of the 431 projects that had been announced were stopped prior to completion, and 21 percent of those "terminated" projects were joint ventures. One action that the ATP took to reduce the problems encountered by joint venture applicants was to establish a Web-based "alliance network" to provide a "best-practices" tutorial for companies thinking of applying to the ATP as a joint venture. This is a bulletin board that companies can use to help locate possible partners, and it includes a discussion forum for exchanging ideas about problems and solutions. As another example, we are in the process of examining the success of award recipients in commercializing their technologies as a function of the way that projects are structured. This should provide useful insights into project selection decisions.

Measure Against Mission

There are some basic principles to follow in setting up an evaluation program. One basic principle is to measure against the mission. We examined our statute for the essential mission and goals against which to measure the program's success. Congress directed the ATP to assist U.S. businesses "in creating and applying the generic technology and research results necessary to—commercialize ... rapidly...." The statute requires that the ATP not fund programs that would be conducted in the same time period without the ATP. We use the terms "cycle-time reduction" and "acceleration" to capture the ATP's impact on the timing of research and development and subsequent commercialization of technologies developed in the funded projects. We have found that the ATP addresses two types of delay: the difficulty in starting a project and the pace with which the project is performed.

The statute specifically calls for the refinement of manufacturing processes. The ATP funds projects across a wide range of technology areas, including substantial attention to both process technologies and technologies that underpin new and improved goods and services. The statute also emphasizes collaborative activities. It highlights the role of small businesses. It states that the ATP is to focus on improving the competitive position of U.S. businesses. And, the statute indicates throughout that the technologies funded by the ATP are to have the "potential for eventual substantial widespread commercial application." Below is a list of key elements from the ATP statute. In paraphrased form, the statute calls for:

- Creation and application of high-risk, generic technology
- Acceleration of R&D and commercialization
- Refinement of manufacturing processes
- Collaborative activities
- Improved competitiveness of U.S. businesses
- Widespread applications and broad-based benefits

A Logical Framework for Evaluation

Another basic principle in setting up an evaluation program is to link in a systematic way the program's activities to its mission; the outputs to the activities; and the shorter- and longer-run outcomes to the outputs. In the parlance of program evaluation, this is sometimes called developing an "evaluation logic model," which links ATP's mission to activities, outputs, intermediate outcomes, and final outcomes.

Examples of ATP activities include holding competitions in which businesses submit technology development proposals and making awards to applicants. Examples of ATP outputs are increased R&D spending and technical goals accomplished. Examples of ATP intermediate outcomes are knowledge dissemination through patents and papers, company growth, licensing agreements, and early sales of new products. Examples of final ATP outcomes are productivity improvements, gains in international market share, employment gains, increases in gross domestic product, and improvements in living standards and quality of life for the taxpayer. These examples illustrate the linkages between mission, activities, ouputs, intermediate outcomes, and long-term outcomes.

Increasing Spillover Benefits over Time

Time is an obvious issue in measuring impact. It is *not* a simple matter of "R&D dollars in and economic impact immediately out." Research and development both take time; commercialization of goods and services based on the technology platforms developed in ATP projects takes more time; and widespread technology dissemination can take a very long time. It is essential to understand the long-term nature of ATP investments.

Figure 1 illustrates conceptually the time entailed for ATP projects to be performed and to have impact. Time in years is measured along the horizontal axis, starting with the announcement of an ATP competition for proposals, progressing to the announcement of awards, then indicating completion of projects in two to five years (on the average between three and four years), followed by the postproject period. Economic impact is measured conceptually on the vertical axis. The lower curve illustrates slowly rising benefits to awardees. The upper curve illustrates increasing total economic benefits to the nation over time. The difference between the two curves indicates spillover benefits that extend beyond the ATP award recipients, as others benefit from the new technologies. Spillovers may include market spillovers, knowledge spillovers, and network spillovers. The kinds of effects that may be expected for a successful project in each of the time periods are listed in the shaded columns. Of course, the exact timing depends a great deal on the technology and the industrial sector in which it is applied.

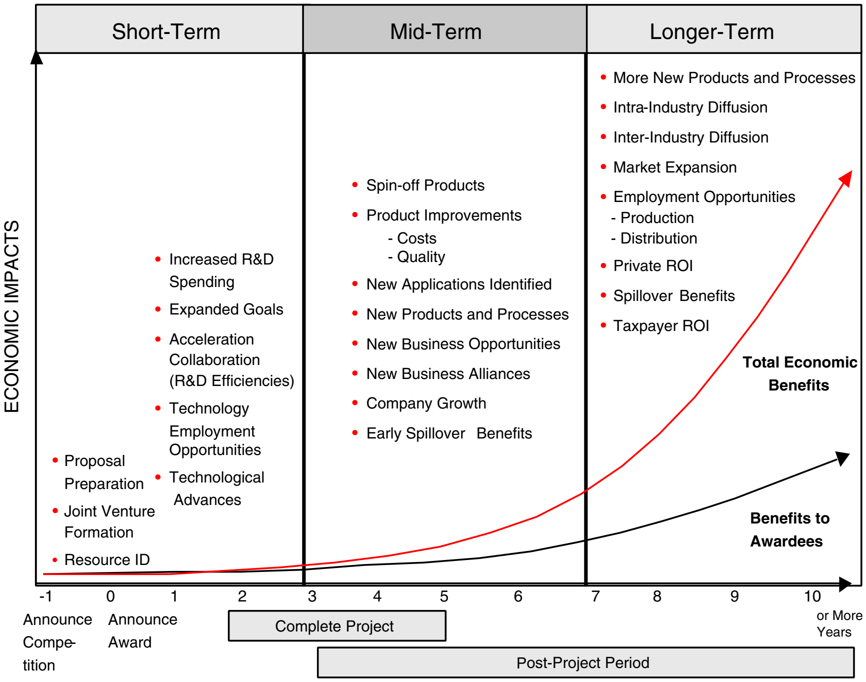

FIGURE 1 Conceptual Timeline for ATP's Expected Impacts.

There is certainly no "one-size-fits-all" illustration. This conceptual piece is intended only to give an idea of how time figures into the unfolding of events surrounding ATP projects. From an evaluation perspective, the timeline means that, in order to meet pressing requirements for evaluation, we have had to make use of "indicators" of progress, as well as projections in estimating long-term impacts. With the passage of more time, retrospective estimates of project benefits based on a long view back will become more feasible.

Two Paths to Long-Run Economic Benefits

The ATP's success is tracked along two principal paths, one that can be described as a direct marketplace path, and the other as a more indirect path of knowledge and institutional effects. Of course, both paths are conditional on the technical success of the projects funded, which means that technical progress against the project goals is also important. Looking at the direct marketplace path of success, we ask if the technology developed in an ATP project is being commercialized in the postproject period in one or more applications by the ATP award recipients or their direct collaborators. (Note that in this context "commercialization" means the use in production of process technology as well as the sale of goods and services.) We also look at how users of the resulting products and services are affected. This is the ATP's principal path for accelerating commercialization of the technology as called for by its mission.

Looking at the indirect path, which actually may be an array of indirect paths, we investigate whether the knowledge and institutional effects created by the project may be influential outside the boundaries of the ATP-funded project, eventually translating into measurable marketplace effects. These indirect effects may be as important as, if eventually not more important than, the direct effects, but they typically occur at a slower pace than the direct effects, tend to be serendipitous rather than intended, and provide less opportunity for deliberate acceleration of national economic benefits. The direct and indirect effects can be characterized as follows:

- Productivity gains
- New business opportunities
- Employment benefits
- Higher standard of living
- Health, safety, and quality of life gains

Both paths may lead to substantial spillover effects. Market spillovers in the form of consumer surplus benefits tend to be dominant on the direct path, and knowledge spillovers and network spillovers tend to be dominant on the indirect path. However, the interplay of the various spillover effects is complex. For example, reverse engineering of products and processes produced on the direct path can generate knowledge spillovers, and competitive effects from knowledge spillovers may further increase market spillovers.

The ATP's evaluation program places importance on measuring the spillover effects—benefits (and costs) not captured by (or incurred by) the innovator/investor. Spillover measurement is quite challenging for evaluators, and the ATP seeks through its evaluation program to advance the state of the art in spillover measurement.

The ATP Aims to Select Projects with High Spillover Potential

The ATP not only focuses on spillover effects in its evaluation program, it also aims to select technologies that are particularly rich in spillover potential. These include pathbreaking technologies (e.g., Tissue Engineering's marriage of textile weaving techniques with biological materials); infrastructual technologies (e.g., printed-wiring-board technologies); and multiuse technologies (e.g., ABC's dimensional control technologies and Extrude Hone's flow-control technology). With more evaluation experience, we hope to improve further our ability to select through peer review those projects with higher-than-average spillover potential.

Better Tools for Assessing Technology Impacts

We have found that evaluating a complex program such as the ATP requires all of the evaluation tools in the tool kit—and then some—to address the many questions raised by ATP management, industry, Congress, and others. Figure 2 summarizes the main approaches that we are taking.

Multiple Approaches to Evaluation

Statistical profiling of
✓ Applicants
✓ Projects
✓ Participants
✓ Technologies

Real-time moinitoring of research
✓ ATP project teams
✓ Company technical reports

Progress measures derived from
✓ Surveys
✓ ATP's "Business Reporting System"
✓ Other databases

Status reports on completed projects

In-depth case studies
✓ Private and Social returns
✓ "Public" returns ("additionality")

Evaluation tool development

Statistical and econometric analysis

Special issue studies

Comparisons with counterpart programs abroad

FIGURE 2 Multiple Approaches to Evaluation.

Our first emphasis was on being able to answer all of the who, what, where, and when questions about the projects we had funded. Of course, we also needed immediately to provide for real-time monitoring of the research—through project teams and company technical reports. To analyze and report on progress toward meeting longer-run goals, we have found particularly helpful the periodic surveys that have been conducted, and our internal "Business Reporting System," which collects data for all projects from practically all participating organizations and has done so since 1992.

The just-released report on completed projects is Volume I in an ongoing series that will report accomplishments several years after project completion for each and every project.[2] We see a substantial demand for this type of report. Being developed in conjunction with the "status reports," as we have dubbed them, is another database that we are using in an experimental way to test the relationships between project characteristics and early postproject accomplishments.

In-depth case studies have proven invaluable in understanding complex projects and in quantitatively documenting impacts, but these studies are too resource intensive and time-consuming to conduct for every project. We have completed about ten thus far, and have several additional in-depth case studies currently under way. In a few cases it has been possible to bridge from microeconomic estimates to macroeconomic projections of national impact. The in-depth case studies typically estimate returns to the direct award recipients (private returns), returns to the nation (social returns, which include private returns and spillover effects), and returns specifically on the ATP's investment (what we call "public returns"). These studies have looked more extensively at the "additionality" question, comparing the "with ATP outcome" with a counterfactual "without ATP outcome" to estimate the difference.

Along the way, we saw both the need for and the opportunity to improve the tools—the models, methodologies, and databases for assessing the program. We have commissioned others to develop, test, and apply new evaluation models and methodologies, and to compile databases. As I mentioned previously, the Economic Assessment Office within the ATP also has compiled databases to support evaluation research. These tools we expect to be of general benefit to researchers working in the field of technological assessment.

In addition, we have needed to address what I will call "special-issue questions." These include such questions as: How are small businesses faring in the ATP? What has been the role of universities and the effect of their participation in ATP projects? What are the similarities and differences of ATP-funded joint ventures versus those funded outside the program? How does receiving an ATP award affect the ability of companies to attract other sources of funding? How can effective control-group studies be formulated?

---

[2] Long, *op.cit.*

We also have identified and followed a number of counterpart programs abroad. Most of the world's industrialized nations have ATP-like programs. We identify program features of particular interest and compare them with the ATP. We also are interested in the evaluation efforts of these counterpart programs. Last summer, we compared notes in an international conference on the economic evaluation of technological change, sponsored by the ATP in cooperation with the National Bureau of Economic Research (NBER).

In today's symposium, there is insufficient time to address all of the ATP-sponsored assessment studies and results. Today you will see several examples of ongoing work, such as the Zucker–Darby research in the next presentation that is of particular interest because of its development of control groups. In later panels, you will see several examples of research that is completed, such as the Lerner–Gompers research, and also the Vonortas work, which also used a control group in comparing ATP-funded joint ventures to other joint ventures. Because of the limited time, I will merely comment that completed ATP evaluation studies are listed in a Bibliography of Studies by Staff and Contractors of the Economic Assessment Office, which is available at our Web site.[3] Much has been done toward evaluating the ATP; much remains to be done.

Substantial Involvement of Outside Experts

In formulating our evaluation program and identifying the important questions to address, we have had the advantage of advice from leading experts in the field. In the up-front evaluation that takes place in real time during the selection of projects for funding, extensive use is made of outside reviewers. Although we usually do not think of this as part of evaluation, peer review is, in fact, the most common method used to assess research projects. We also have had valuable input from the NBER. Professor Zvi Griliches, well known and highly regarded in the field of evaluating technological change, has co-chaired a series of evaluation planning workshops for the ATP—both at NIST and at NBER, with the first taking place in 1994. These workshops have been well attended by other experts in the field. Professor Edwin Mansfield, another leading figure in the field of evaluation, worked with us prior to his death. Professor Adam Jaffe has played a major role in instructing the ATP on the issue of spillovers, as well as in reviewing evaluation studies in his role as coordinator of the NBER research on the ATP. Important contributions to the ATP's evaluation have been made by many other academics, private consultants, and nonprofit organizations.

In addition, we are developing closer interfaces with other funding sources, especially the venture capital community. The ATP has very different criteria for selecting projects than venture capitalists have, and the two fit together in the

---

[3] See the ATP bibliography at http://www.atp.nist.gov/eao/folio.htm

R&D funding landscape in a complementary, rather than competitive, manner. Venture capitalists and "investment angels" are often important sources of funding, particularly for ATP awardees that need to raise substantial amounts of outside capital to complete research and commercialize results.

Many of the ATP's small-company award recipients are eager to present their newly acquired business opportunities to private-sector funders toward the end of their ATP projects. With the objective of strengthening future odds of success of the technologies it has funded, the ATP occasionally hosts events that bring together ATP awardees with potential investors and partners in commercialization. The John F. Kennedy School of Government at Harvard University is leading an effort for us to investigate and compare the decision processes of the ATP, of the large, medium, and small businesses, and of venture capitalists, toward the goal of ensuring that the ATP avoids displacing private capital.

Three Tests for the ATP's Success

Ultimately, there are three tests for the ATP's success:

- Although some projects will fail and some will deliver less than anticipated, overall, the portfolio of projects must yield large net social benefits, that is, large benefits to the nation in excess of all costs. It is critical to take a portfolio approach in evaluating the success of the ATP. The program must be allowed to have some individual projects that fail if it is to undertake the high-risk projects that, by their very nature will sometimes fail. The ATP should be judged on its overall effect, not on the success or failure of individual projects.
- The ATP must make a difference. That is, it is not enough that the portfolio of projects yield large net benefits; a sizable share of these net benefits must be attributable to the ATP.
- Net benefits to the nation must be much greater than the summation of private returns to the awardee innovators; that is, there must be large spillover benefits to others.

A subset of ATP projects is now completed, and the first 38 have been subjected to analysis in the post-project period. According to the researcher, the projected benefits of just several of these early projects are sufficient to more than compensate for all of the costs of the ATP so far—and the part of the projected benefits attributable directly to the ATP are also sufficient to meet this test.[4] Not surprisingly, some of this first group of projects are performing better than others. As you will see from Volume I of the status report, we are documenting what is

---

[4] Long, *op. cit.*

working and what is not.[5] And, as I mentioned at the beginning of my remarks, we are drawing lessons gained along the way to improve the program.

Lastly, let me just say how much we welcome this effort by the Academy to draw on the ATP's evaluation program as it undertakes a broader assessment of government-industry partnerships.

PERFORMANCE MEASURES AS INDICATORS OF ATP EFFECTS ON LONG-TERM BUSINESS SUCCESS

Lynn Zucker
Michael Darby
University of California at Los Angeles

Dr. Darby said that the research he would talk about today might well qualify as generic precompetitive enabling research, in that an objective of the Zucker–Darby research is to build a database that would enable many researchers to analyze the ATP. The research is collaborative because they are working with members of NBER as well as with Maryellen Kelley and Andrew Wang at the ATP.

Research Questions

In their study, Zucker and Darby have begun to gather archival data about ATP firms and comparable firms not in the ATP so that something can be said about how and whether the ATP makes a difference. They are concentrating on trying to say something about program awardees before, during, and after their participation in the ATP. Three basic comparisons are being sought:

- Within the ATP, what are the differences between joint ventures and single applicants?
- What are the differences between ATP-funded firms and non-ATP-funded firms?
- What are the differences between ATP joint ventures and joint venture that do not receive ATP funds?

The research will explore firms within broad science areas and broad technology areas. The time horizon for the firms in the data set will be ATP awardees from 1990 to 1998. The data set at present looks at principal ATP awardees; this does not therefore include subcontractor ATP firms, but it is hoped that they will be included in the future. Overall, their data set at present includes 628 unique organizations (i.e., firms, universities, and national laboratories).

---

[5] *Ibid.*

A key outcome measure for the organizations to be studied will be the number of patents filed. For small businesses in the data set, Zucker and Darby will use as an outcome measure whether the business made an initial public offering. Whether small firms were able attract venture capital is another outcome measure for small firms. This would help to test the "halo effect" hypothesis with respect to the ATP, that is, whether receiving an ATP award increases the probability of obtaining venture capital.

Preliminary Results

Dr. Zucker then presented the preliminary results of their analysis, emphasizing that the results were preliminary and subject to change as the research progresses. In this preliminary phase, Zucker and Darby focused on two years of data, 1991 and 1992, which comprised 110 organizations and principals only, not subcontractors. The analysis looks at the total number of patents issued two years before an ATP award, and the total number of patents issued 1,095 days after the start of the ATP award. Dr. Zucker noted that changing the timeframe does not change results.

In describing the data set that she and Dr. Darby are assembling, Dr. Zucker said that, not surprisingly, the large businesses tend to have filed a number of patents in the evaluation period, whereas small companies did not. For small businesses, there may be a lag problem; a number of such businesses were founded shortly before receiving ATP awards; it is unlikely that they would generate patents within the first few years. For medium-sized businesses, more have patents than do not, whereas about half of the nonprofits have patents. During the period studied, universities tended to have patents, which is not a surprise in light of the incentives provided by the Bayh–Dole Act.

In looking at pre-ATP and post-ATP patent activity, although large companies account for a large amount of patent activity, they do not account for an extraordinarily large share of the difference across the two time periods. In looking at a sample of companies and organizations that excludes large businesses, there is a small increase in patenting activity among small businesses in the post-ATP award period, and a larger increase in patenting among medium-sized businesses. For nonprofits, there is a small decrease, although the sample is small, and universities show a substantial increase in patenting activity post-ATP.

The Zucker–Darby analysis also examines pre- and post-ATP patenting activity by project type. In the data set, there are far more joint ventures than single-company ATP projects. For joint ventures, the post-ATP period shows an increase in patenting activity, but for single-company ATP awardees, there is no increase in patenting activity.

In summary, Dr. Zucker reiterated to the audience that the results presented are preliminary and subject to revision as the project unfolds.

DISCUSSANT

J. C. Spender
New York Institute of Technology

Dr. Spender remarked that some may look at academic research on the ATP and ask whether it is politically viable; others may dismiss the research as not altogether meaningful. For Dr. Spender, the debate over the ATP and academic research on it involves what he calls "interpretive flexibility" in which a variety of different actors have a variety of different views on the program. He recalled the comments of Dr. Nelson and Dr. Spencer characterizing the ATP as an experiment in technology policy. Although true, Dr. Spender also said that it is true that the ATP is also an experiment in evaluation research.

Evaluation is increasingly important in all public programs as people demand more accountability for expenditures; it will not suffice to say that there should be no public expenditures in areas such as technology development. The question is how to spend public funds properly.

A Multidiscplinary Evaluation Approach

In the evaluation of technology programs, this is an area of profound complexity in a technical sense because of the multidisciplinary nature of the task. Because of this complexity, the conduct of evaluation and its interpretation should not be left solely to economists. Sociologists, anthropologists, political theorists, historians of technology, and others should be drawn into assessment of technology programs. It is a rich area of academic inquiry and of growing importance as the need to understand technology programs and their consequences grows.

Dr. Spender said that the ATP invites three classes of discussion:

1. outcomes, which Dr. Ruegg addressed;
2. efficiency of operations, which Dr. Powell addressed; and
3. origins of the program, which Dr. Hill addressed.

With respect to origins, Dr. Spender said that additional research into the program's history and its political context would be useful. Most people in the audience were acutely aware of the varying degrees of political hostility that the ATP has faced. This political context places operational constraints on the program, which in turn can feed back into the political environment and affect the program's long-term viability. Another avenue of historical research is comparing the ATP to similar programs overseas.

Addressing program outcomes, Dr. Spender said that there may be a "low-hanging fruit" phenomenon in thinking about this issue. In the evaluation arena, researchers have a number of tools readily available to evaluate the ATP, but by its very nature, the ATP challenges researchers to develop new evaluation tools.

Adding to the challenge is that researchers know that the developing new evaluation tools will have profound political consequences. Dr. Spender encouraged researchers to reach for "higher hanging fruit" in searching for ways to better understand, for example, the theory of spillovers and how private goods, such as industry R&D are transformed into public goods. Dr. Spender also said that better understanding of "knowledge flows" is necessary, that is, tracking the generation of knowledge through organizations. This may enhance the understanding of spillovers.

Dr. Spender said the "multidimensionality" is an important concept for ATP evaluators to keep in mind. By that he meant that purely unidimensional analyses, whether anthropological, economic, or political, miss the challenge of properly evaluating the ATP. It is better to develop tools that are truly complex, and therefore capture a project's outcomes.

Capturing the ATP's Complexity

From his own ATP evaluation experience, looking at the Auto Body Consortium and the Printed Wiring Board project, capturing the project's complexity is key. Taking the projects as "self-organizing systems," Dr. Spender said, helped him to gain greater understanding of the projects. In his view, the two ATP projects that he explored were "nested sets of semi-self-organizing systems." The project may be regarded as a self-organizing system or the firm may be so regarded. Alternatively, the ATP within an industry sector, with the latter regarded as a self-organizing system, may be the proper perspective through which to view the ATP. Taking the self-organizing metaphor further, an ATP grant is something that can alter the initial conditions of an industry's trajectory, and even a small change in initial conditions may have large consequences as a sector self-organizes.

In concluding, Dr. Spender encouraged the development of better evaluation tools for the ATP and again emphasized the need for a multidisciplinary approach to evaluation.

QUESTIONS FROM THE AUDIENCE

Following up on Dr. Zucker's presentation, Dr. Flamm asked why patents would be the appropriate measure of ATP outcomes. He noted that one could argue that increasing patent activity was not an ATP objective, but rather encouraging private investment, with public assistance, in projects that would have large spillovers for the economy at large.

Dr. Zucker responded that their study was not focused solely on patents, but on a variety of possible impacts from the ATP. Patent data were one useful way to quantify impacts. Dr. Zucker also said that patents had more spillovers than trade secrets, for example. Citations to patents could be used as a measure of spillovers, she said, while acknowledging the imperfection of patents as a proxy for spillovers.

Dr. Flamm cautioned that one might find the same number of patents pre- and post-ATP in a company or companies, and draw the inference that the ATP had had no effect. It is possible, however, that the ATP encouraged companies to generate patents with greater spillovers than before, meaning that the program made a difference. Dr. Zucker responded by saying that she and Dr. Darby were developing a way to address the quality of patents among ATP recipients.

Alan Lauder of DuPont asked Dr. Ruegg about the 12 project terminations in the ATP and stated that often we can learn more from failures than from success. What, Mr. Lauder asked, has been learned from these failures?

Dr. Ruegg said that the 12 projects were terminated in the time horizon of Dr. Long's study and, since then, 12 more have been terminated. This amounts to 6 percent of all ATP projects. About 20 percent of the terminated projects are joint ventures that did not get off the ground. Another 20 percent have been small companies that have gone bankrupt. One-third of the terminations is due to a change in company management or strategy; something internal changed that caused the company to no longer pursue the project. A final class of projects was terminated for technical reasons; the R&D team believed that technical challenges were too great to be overcome in the context of the project.

Panel IV:
Capital Markets and New Technologies

INTRODUCTION

Kenneth Flamm
University of Texas at Austin

Dr. Flamm set the stage for the panel by raising three questions about the relationship between capital markets and the Advanced Technology Program (ATP).

Market Imperfections

When one thinks about the ATP, there are two kinds of market imperfections that might justify government intervention into the marketplace. The first, which was discussed extensively in the morning session, is imperfections in the market for research and development (R&D). This often is referred to as the "appropriability problem" in R&D, whereby the investor in R&D does not fully capture the ensuing economic benefit. In other words, the social return to R&D investment exceeds the private return.

As he understood the ATP, Dr. Flamm said that this was the original intent of the program, that is, to foster investment in precompetitive generic technologies in areas in which the ATP's framers believed social returns would exceed private returns.

Imperfection in capital markets is the second market failure that the ATP might address. Joshua Lerner from Harvard Business School will talk about the role of venture capital in capital markets. On the basis of his familiarity with

Dr. Lerner's work, Dr. Flamm anticipated a discussion of the information asymmetries that venture capital addresses, that is, the ability of venture capitalists to better assess and monitor technology investment opportunities than other financial institutions, thereby addressing underinvestment in technology.

Dr. Flamm pointed out that the capital markets and appropriability issues are completely separate. In the presence of perfect capital markets, there still may be underinvestment in R&D because of appropriability problems. An interesting aspect of Dr. Lerner's empirical work is that it shows the ways in which venture capital addresses imperfections in capital markets, but it also shows that venture capital does not address all imperfections. Indeed, Dr. Lerner's work suggests ways in which venture capital may create new problems in capital markets.

A question for the ATP is whether the government should take aim at areas in which capital market imperfections result in insufficient R&D investment, and then unleash the ATP policy apparatus at identified target areas. Dr. Flamm expressed hope that Dr. Lerner would address this.

Terminological Confusion in the ATP

In the ATP, terms such as small firms, small start-up firms, and high-technology firms seem to be used interchangably. Dr. Flamm said that these are really different populations with small areas of intersection, but that the failure to understand this leads to confusion. For example, small firms often are portrayed as if they were all high-technology start-ups, which is not the case. Dr. Flamm suggested that panelists be clear about the type of firm or firms that they were talking about in their remarks.

Definition of High-Technology Firms

Dr. Flamm also suggested that we should be careful about defining high-technology firms, asking whether it is accurate to identify R&D only with high-technology firms. There are many products in the economy that use high technology in production or distribution, but these firms would not necessarily be characterized as high-technology firms, and many such firms do not conduct much, if any, R&D. Dr. Flamm recalled a recent *Wall Street Journal* article describing an Internet furniture start-up that a venture capital firm was considering funding. Such a firm probably is not what we think of when we talk about high-technology firms or R&D-intensive firms. The firm uses advanced technology, but R&D, and incentives to invest in it, may not be an issue for this firm. Dr. Flamm asked panelists to distinguish between high-technology or R&D-intensive firms and firms that are users of R&D and high-technology components.

VENTURE CAPITAL AND THE ATP

Joshua Lerner
Harvard Business School

Dr. Lerner said that his plan was to address many of the issues that Dr. Flamm mentioned about the connection between venture capital and public policy. His talk would focus on public venture capital, or public programs to fund innovative start-up programs, and the venture capital sector more generally. Dr. Flamm noted that his research has been conducted with his colleague at Harvard, Paul Gompers, and includes large-sample analysis and case studies. For today's discussion, Dr. Lerner planned to concentrate on the case studies.

In setting the stage for the case studies, Dr. Lerner first characterized what venture capital is. He defined venture capital as the subset of all the money that is available for entrepreneurial companies; it is an organized pool of funds managed not by people who provide the money (which typically are pension funds), but by people with some expertise in high-growth areas. These funds take an equity stake in the companies in which they invest. There is very much a "venture cycle" in which the General Motors Pension Fund or the Harvard Endowment provides funds to venture capitalists, who then provide money to the start-ups—the Netscapes or Genentechs of the world.

The U.S. venture capital business has become the envy of the world, but it is worth underscoring that it is a very young industry. The first venture capital fund was not established until immediately after World War II and it remained a sort of boutique industry through the 1970s. Very recently, venture capital activity has overwhelmed earlier investment levels, rising to an estimated $15 billion to $20 billion in the United States in 1997.

Role of Venture Investors

A crucial point to keep in mind when thinking about venture capital, Dr. Lerner said, is that funding is often the least important thing going on when all other aspects of financing are taken into account. For a start-up company, the entrepreneur is usually one of the few persons in the world, perhaps the only one, who fully understands the technology. A traditional financial institution may not have sufficient expertise to understand the technology and its market potential. Venture capitalists employ different strategies to address this information problem, from sitting on the board of start-up firms to structuring other sophisticated financing packages. These strategies enable venture capitalists to acquire information about opportunities and problems, something that other financial institutions are not well equipped to do.

On the basis of available evidence, namely, that, over time, venture-backed firms tend to outperform similar firms not backed by venture capital, it appears that venture capitalists fulfill a useful role in the finance and innovation system. Taking the biotechnology industry as an example, this industry has created between 1,500 and 2,000 firms since its start in the early 1970s. Approximately one in three has received venture financing. However, the one-third of biotechnology firms that have received venture financing dominates most measures of innovation in the industry, from number of drugs approved to patents issued.

Role of the ATP

Given the unique niche that venture financing fills in the financial world, Dr. Lerner and his colleagues turned to the question of where the ATP fits. As noted earlier, his research includes empirical work and case studies and today his remarks would focus on the case-study results.

One lesson from the case studies is that, if a goal of the ATP is to assist companies on the path toward commercialization, policy makers should examine whether companies being funded have the potential to attain commercial success. Having done field research on the ATP and the Small Business Innovation Research (SBIR) program, it becomes apparent when talking with ATP and SBIR firms is that there is a clear bifurcation among firms. Some firms view the ATP or SBIR award as a bridge toward commercialization and perhaps an initial public offering (IPO). Others see themselves as contract R&D companies, with the ATP or SBIR grant as a way to conduct research and perhaps license it to others, but not as a vehicle to broader product success in commercial markets. It is questionable as to whether some of these companies would ever be fundable by venture firms.

A second lesson is that venture financing is very heavily targeted. Since the early years of the venture capital industry, approximately 80 percent of venture funds has gone to information technologies (computer hardware and software) and the life sciences. There is a much broader range of technologies, such as advanced materials, but venture financing has not focused on them. Today, the venture industry appears fixed on finding the next “whatever.com” at the expense of less fashionable technologies that are nonetheless promising. Public programs may therefore alleviate the tendency of the venture industry to concentrate on a narrow set of technologies. In any event, policy makers should guard against channeling public funds to areas—such as Internet companies or human genome sequencing firms—that already are well funded by venture capitalists. Public money might be better spent in support of companies in areas that venture capitalists are ignoring.

The Focus on Precompetitive Technologies

Dr. Lerner noted that his final point was likely to be controversial, and is derived from the ATP’s enabling legislation, as opposed to administrative decisions by ATP program officials. The ATP's original intent was to encourage pre-commercial R&D. For many small entrepreneurial companies, however, drawing a distinction between pre-commercial and commercial research can be meaningless or counterproductive. Some case studies indicate that there were well-intentioned efforts to keep the R&D of some ATP recipients in the precompetitive realm. However, these efforts may not have been helpful from the company's perspective. Although it is likely that there is no easy answer to this issue, Dr. Lerner suggested that this issue should be raised with the ATP officials and congressional staff.

In conclusion, Dr. Lerner made three points:

- The venture capital market is a substantial one and also is very complicated.
- Policymakers should carefully consider where public programs fit in the context of venture capital financing.
- There is a role for well-designed public programs to provide R&D funds for innovative companies, but the program design should be carefully thought through.

A VENTURE CAPITALIST PERSPECTIVE

Todd Spener
Charter Financial

To put his remarks in perspective, Mr. Spener noted that Charter Financial is backed by Warburg Pincus, a $7 billion venture capital fund, the largest in the United States and perhaps in the world. Prior to joining Charter Financial, Mr. Spener served as the chief financial officer of a company that received an ATP grant, giving him a unique perspective on the program's operations.

Based on his experience, he sees the ATP serves as a validation of technology. Venture capitalists are good at assessing risk when it comes to business execution and business plans. Although some venture capital funds have technology experts on staff, most are more expert on business issues. The ATP serves to mitigate technology risk for venture capitalists. Because ATP is a competitive program, venture capitalists can feel comfortable that an ATP-funded company is technologically sound.

Consequently, with an ATP grant in hand, a company stands a better chance of gaining venture capital financing, and also has access to other benefits, which Dr. Lerner touched on, such as qualified business people and strategic partners, both of which will facilitate the commercialization process.

Obtaining Financing for a Start-up

Mr. Spener described the process by which a venture-backed company obtains venture capital. The entrepreneur first goes through the "Rolodex process" in which he or she calls family and friends and tries to obtain funds from them. The next step is the "angel phase" whereby the entrepreneur seeks out an experienced and successful person in the field who understands the technology and has the resources to invest.

Two rounds follow: In the first round, the entrepreneur attempts to convince a sophisticated institutional venture capitalist to invest. The second round is a more strategic phase, in which the entrepreneur targets an experienced venture capitalist who understands the field well and is a savvy investor in the field. Such an investor may be a large firm attempting to diversify its portfolio.

This process is efficient when assessing business risk. However, when the technology risk is high enough to cause investors to pause, the ATP provides a bridge between the technical and business risks.

Private investors, Mr. Spener explained, are motivated by overall returns to their capital. Investors have varying tolerance for risk; high-risk investors may tolerate more losses than risk-averse ones, but they will need some "big wins" to balance their tolerance for risk. Other investors may prefer a greater number of wins, with modest returns, and few large losses. The ATP fits in the picture in that it can provide "catalyst capital," that is, the grant may tilt the decision of a venture capitalist toward funding a particular firm. Using a sports analogy, Mr. Spener said that the ATP provides a "farm system" for venture capitalists, or a proving ground for technologies, which allows some venture capitalists to call them up to the "big leagues" of venture funding on the basis of good performance in the ATP competition.

ATP and Patient Capital

Mr. Spener pointed out that, as recently as the 1980s, inefficient capital markets and the lack of patient capital in the United States were cited as the reasons for poor U.S. economic performance, downsizing or "right sizing" of U.S. companies, and widespread job losses. Today, Mr. Spener noted, our technology industries and system of finance are the envy of the world, raising the question as to what is patient capital. Is it a corporation reinvesting retained earnings into the company for growth? Or is it the venture capitalist who may invest in the Stanford graduate who has a great idea, even though he or she has yet to buy a dress suit? In Mr. Spener's view, the ATP is among the most patient of patient capital.

In summing up, Mr. Spener said that the gap in technology investment is the risk associated with new technologies, and the bridge is the ATP.

SMALL FIRM EXPERIENCE IN THE ATP

Mitch Eggers
Genometrix, Inc.

Origins of Genometrix

Dr. Eggers opened his remarks by describing the origins of Genometrix and how an ATP grant contributed to Genometrix's growth. In the early 1990s, Dr. Eggers had a vision of combining microelectronics and electrobiology into what is now known as the electronic DNA chip. Dr. Eggers and his colleagues demonstrated initial feasibility working with Baylor College of Medicine and the Massachusetts Institute of Technology (MIT), and presented the ideas to companies such as Texas Instruments and Hewlett Packard. Researchers at the companies were intrigued, but management at large electronics companies chose not to pursue the manufacture of the electronic DNA chip.

Dr. Eggers and his colleagues therefore turned to the ATP for funding and submitted an application with eight other institutions. Although MIT provided the manufacturing facility to build prototype chips, no one seized the manufacturing opportunity on a commercial basis. Genometrix was incorporated in 1993 to pursue commercial opportunities and, in 1994, received $300,000 in a convertible note from a venture capitalist to begin operations. Dr. Eggers emphasized, however, that it would have been impossible to raise the venture financing without the ATP grant in hand. Genometrix won the largest ATP award in 1994, $9 million from the government and another $9 million from collaborative partners.

Since 1994, Genometrix has grown from 3 employees to 40 full-time employees, 20 percent of whom have doctorates. The company has over 20 partners, including MIT and Motorola. Revenues for Genometrix were $2 million last year, projected to be $7 million for next year, with an initial public offering (IPO) planned for next year. The ATP grant has played an important role in the company's growth.

Social Value of Genometrix Technology

Recalling the earlier discussion about social versus private returns, Dr. Eggers said that Genometrix's technology has a social dimension to it. Genometrix's DNA chip is a very efficient way to develop "genotype services," which involves obtaining a DNA fingerprint from a blood sample. The DNA fingerprint then is correlated with a patient outcome. A pharmaceutical company then can access a database with thousands of records containing the DNA fingerprint and patient outcomes and tailor medications more precisely to patients' genetic makeup. In the future, rather than people taking medications that may or may not work, medications will be crafted for a patient's individual needs. A DNA test would be done prior to prescribing medicine, and the test would reduce the number of adverse reactions to medication. This is a serious problem; over 100,000 people in the United States die each year from adverse reactions to medication, the fourth largest killer in the country. For tens of dollars, Genometrix's simple DNA test can largely eliminate this problem.

This kind of testing could not have been done in a cost-effective way two or three years ago. Recently, Genometrix completed a study for the Food and Drug Administration (FDA) in which the company took over 800 samples of patients' blood—which would contain more than 10,000 different genotypes—and determined the correct genotypes. The FDA already had determined the genotypes on its own and this had taken FDA one year. Using its automated platform, Genometrix correctly determined the genotypes in one week. Genometrix projects that, within a year, it will be able to do the same task in one day.

The Genometrix technology therefore will have strong social returns as it improves the quality of patient care and saves lives, in addition to commercial impacts when the company goes public. For Genometrix, the ATP has meant an opportunity for individuals such as Dr. Eggers and his colleagues to take a revolutionary idea and move it into the commercial market.

SMALL FIRM EXPERIENCE IN THE ATP

Mark Pittenger
Osiris Therapeutics

ATP's Role in Osiris

Dr. Pittenger described Osiris Therapeutics as a young biotechnology company from Baltimore that has been organized to commercialize mesenchymal stem-cell technology. Osiris isolates stem cells from bone marrow and uses the cells to generate tissue. Osiris is directing its technology toward cancer therapy, cartilage regeneration, and bone generation. Gene therapy is another potential use of Osiris's technology.

The ATP grant to Osiris was made to develop muscle regeneration techniques, specifically for cardiac muscles. When the heart is damaged, the lack of stem cells in the heart prevents it from repairing itself. With Osiris's technology to generate stem cells, the regeneration of cardiac muscle is now possible. For cardiac muscle regeneration and other purposes, Osiris uses stem cells from bone marrow to regenerate other tissues elsewhere.

The ATP funding has allowed Osiris to venture into areas where the company otherwise would not go, because of competing demands internally on Osiris's resources. As the principal investigator on the cardiac project, Dr. Pittenger has had to struggle to find space, personnel, and resources to pursue the research. The ATP grant has greatly alleviated that struggle.

Sources of Financing for Osiris

Because Osiris has been able to obtain financing from other private sources, it has not sought venture capital. In the past two years, Osiris's expansion has been enabled by a joint venture with Novartis Pharmaceuticals. In regard to the ATP grant, the technology being developed under that grant has not advanced to the point where Osiris has sought outside partners. In 1997, Osiris planned an IPO, but market forces outside its control caused the company to delay that plan. Thus, the ATP money was even more important and enabled Osiris to assemble a team that would not have been possible absent the ATP grant.

Given the presence of strategic partners, it was sensible for Osiris not to pursue venture capital, but the mesenchymal stem-cell technology was too attractive to ignore. This made the ATP an excellent source of funds, as opposed to pursuing venture capital, which may have been hard to obtain and simply was not the route the company wanted to take. Another attraction of the ATP grant is that it is a competitive process with which Osiris is comfortable, and the process allows the quality of the technology to drive the decision making. Finally, the ATP is a useful bridge between outside corporate financing and venture financing, especially because Osiris's stem-cell technology was probably too far from commercialization to interest venture capitalists.

The ATP, Dr. Pittenger concluded, has played an important role for Osiris, and the company is pleased to have recently won a second ATP grant.

QUESTIONS FROM THE AUDIENCE

Dr. Nelson observed that Osiris is an example of an important ATP grant producing exciting results, but he added that intellectual property rights must be considered. He asked Dr. Pittenger what Osiris's intent was with respect to licensing its stem-cell technology. It was Dr. Nelson's belief that the stem-cell technology would have wide applications for university researchers and other companies. An objective of the ATP, said Dr. Nelson, should be to encourage broad dissemination of the technology. Is that Osiris's intent? How did discussions between Osiris and the ATP proceed on intellectual property?

Dr. Pittenger responded that Osiris would like to commercialize the technology as much as possible. As a small company, Osiris recognizes that it does not have the capacity to exploit every commercial potential so as to maximize the health benefits of stem-cell technology. Osiris has had discussions about how to provide the technology to the research community, and much of the information of interest to researchers would be published "quite shortly." As a company, Osiris would like to commercialize the technology as much as possible.

Dr. Flamm followed up Dr. Nelson's question by asking whether the technology would be made available to universities, certainly not for free, but on some preferential basis. Dr. Pittenger said that the Osiris technology would be readily available to university researchers.

Dr. Lerner commented that this discussion was related to Claude Barfield's remarks earlier in the day. Dr. Lerner said that there is a fundamental tension between the desire to place technology in the hands of small companies, which may be effective at commercialization and able to create many new jobs, versus the worry that publicly funded R&D will fall into the hands of a single large company that may not disseminate the technology. Many firms, small ones especially, may find it difficult to obtain venture capital or find strategic partners unless they can obtain exclusive rights to publicly funded technology.

Nicholas Vonortas of George Washington University asked Dr. Lerner what would happen to the supply of venture capital funds if the stock market dropped. Dr. Lerner responded that a forthcoming paper of his to be published in the *Brookings Papers on Microeconomics* explored the sources of venture capital. The most critical determinant in the availability of venture capital is the "supply of good deals" or good investment opportunities. This was more important than the level of the stock market. Factors such as technology-transfer policy and policies that effect incentives for entrepreneurs (e.g., capital-gains tax rates) in turn determine the availability of investment opportunities. These results hold for the United States and other countries.

Clark McFadden of Dewey Ballantine recalled that several speakers said that venture capitalists were good at assessing business risk, whereas the government was good at assessing technical risk. Why specifically is government better than venture capitalists or others in the private sector at assessing technical risk? Is there some special expertise that government brings?

Mr. Spener said that a venture capitalist is unlikely to invest in a technology solely on the basis of validation by the government. A venture capitalist will look for technical assessment and validation and factor it into the funding decision. Whether the validation comes from a government expert or from the private sector is irrelevant. The quality of the expertise, not the source, is most important.

By way of follow-up, Mr. McFadden asked whether the government had any special advantage at the outset in contrast to the expertise of the venture capitalist, or the expertise available to the venture capitalist. Is there anything that leads to a different assessment by the ATP, by virtue of its public status, than by the venture capitalist?

Mr. Spener said that it makes no difference whether the expert conducting the assessment is from the government or the private sector. The background of the assessor, independent of public or private status, is key.

Dr. Pittenger responded that the ATP, and the National Institute of Standards and Technology (NIST) more broadly, has a wide range of experts from which to draw, and these experts see many proposals come into the program. This provides a base of experience in assessing proposals in the government that a venture capitalist would find hard to ignore. Dr. Flamm characterized this as a "portfolio of opinions" theory, in that a venture capitalist would be wise to fold the government's assessment into the family of assessments being considered in a funding decision.

Dr. Lerner said that there is "so much clutter out there" facing venture capitalists with the shear volume of business plans that come to them. Any extra signal, especially for a small firm, can make a difference in the funding decision, and ATP validation, or SBIR for that matter, is bound to carry weight. Mr. Spener added that the fact that the ATP is a competitive program adds prestige to the validation when an ATP grant is awarded.

Mr. Gibson of X-Ray Optical Systems said that, although he was not sure whether the government in general had special assessment expertise, he believed that the ATP and NIST did. For his company's technology, and he suspects for that of many other companies, there are many dimensions to the technology. When talking with people in the private sector and most public agencies, Mr. Gibson usually faced one expert. This expert could see one aspect of X-Ray Optical's technology, but not the whole package. At NIST, however, the agency brought together a panel of experts to review the technical aspects of his company's proposal. For his company, the NIST technical review was different in quality than what X-Ray Optical Systems experienced elsewhere.

Chris Hill from George Mason University said that, if part of ATP's objective is to make ATP-generated knowledge widely available, whether one calls this precompetitive technology or generic technology, what are the mechanisms for the transmission of knowledge by the firms represented on the panel?

Dr. Eggers said that Genometrix has a policy whereby it publishes its research results widely in professional journals. Genometrix does secure intellectual property protection and, for areas that are crucial to its business, Genometrix guards the intellectual property quite carefully. For developments that are not central to Genometrix's core business, the company will license. For example, Motorola came to Genometrix and asked for access to some DNA chip technology to enable Motorola to develop a "point-of-care" technology, that is, DNA testing on the spot. Genometrix recognized that, as a small firm, it could not expect to develop every commercial facet of its technology. Motorola, moreover, has tremendous expertise and market presence in portable electronic devices. This was a natural partnership opportunity, and Genometrix licensed the technology to Motorola.

Dr. Pittenger said that, like Genometrix, Osiris published its research in journals and it had relationships with Johns Hopkins University and the University of Florida. The announcement of the ATP award to Osiris raised the profile of the Osiris technology, which led to invitations for Osiris to present its technology to others. As long as the intellectual property is protected, Osiris is happy to disseminate through journals and conference presentations.

Dr. Long of Business Performance Research Associates asked whether, if certification on technical merit from the ATP or another government agency is a good thing, a venture capitalist should ask a candidate firm if it had applied for a grant from the ATP or other programs and if the firm's application had been denied? Dr. Long also made an observation about Dr. Nelson's comment about intellectual property and knowledge dissemination. Dr. Long said that it is possible to have a rigidly enforced patent and large spillovers. Turning to his second question, Dr. Long noted that there had been no mention about ATP funding displacing venture capital funding; he asked panelists to comment on this apparently missing element in the panel's discussion.

Mr. Spener responded first by saying that he doubted that many venture capitalists had ever heard of the ATP; therefore, it would be unlikely that a venture capitalist would ask whether a firm had applied for, or been denied, an ATP grant. In response to the second question, Mr. Spener did not believe that venture capitalists saw the ATP as competing with them. There are many different kinds of capital in the market, and a provider of capital probably would view the ATP as enhancement to the many types of capital, from venture to mezzanine, that might be provided.

Bill Spencer of SEMATECH pointed out that the venture capital industry has grown tremendously in recent years, leading to the concern that there may be more money than good ideas worthy of financing. With the apparent abundance of capital, whether from venture capitalists or the government, is there a danger of a scarcity of good ideas next year, or 10 years from now?

Dr. Lerner responded by saying that, even with the growth of venture capital in recent years, at $20 billion—if you accept that as a high-end estimate of the venture capital industry—it still represents less than 1 percent of the U.S. capital market. And a typical venture capital firm will fund only 1 out of 100 business plans submitted to it. The growth of venture capital is more attributable to the removal of artificial restraints on the industry, namely the prohibition on pension fund investments in venture capital, than so-called "irrational exuberance" surrounding today's economic environment. In short, Dr. Lerner concluded, it is hard to argue that there is too much venture capital relative to the economy as a whole.

Panel V: Extending Assessment— Challenges and Opportunities

INTRODUCTION

Iain Cockburn
University of British Columbia

Dr. Iain Cockburn set the stage for the panel by commenting on the tension between a publicly funded program, such as the Advanced Technology Program (ATP), and granting proprietary rights to technology developed by recipients. One issue is that, because technologies funded by the ATP are new, the patents issued on them are likely to be very broad. Consequently , there is a legitimate concern about the potential for restricted access to platform technologies. Dr. Cockburn said that people involved in public research and development (R&D) programs are aware of these issues, but it would be worth discussing them in the context of the ATP. Addressing these intellectual property issues is important, and this is why it has come up so many times in the day's discussions.

INFORMATION NEEDS FOR MEASURING SPILLOVERS FROM PUBLIC–PRIVATE R&D PARTNERING

Maryellen Kelley
Carnegie Mellon University and
National Institute of Standards and Technology

Overview

The Advanced Technology Program (ATP) is unique among federal agencies supporting research and development activities in private industry. To merit funding, an industry-initiated project proposed to the ATP has to be focused on an enabling, high-risk technology that has the potential for broad economic benefits. These selection criteria reflect the ultimate long-term goal of the program to achieve greater productivity growth in the economy as a whole through technical advances that become incorporated in industrial processes, and new products and services. In the long run, we expect the economic benefits to consumers and other firms using these innovations to be substantially greater than the profit that the ATP-funded firm makes from developing the technology.

Economists characterize these benefits as spillovers, that is, positive externalities from innovative activity that are not captured fully by the innovating firm. For example, the commercial viability of a technology developed by one company may depend on complementary technologies developed by other firms. A case in point is the ATP-supported technology developed by X-Ray Optical Systems, Inc. In his remarks earlier, David Gibson eloquently described how his company's ATP-sponsored advances in lens technology are enabling complementary innovations by other companies. Through informal alliances with these companies, X-Ray Optical's technology eventually will be incorporated in a variety of applications in a broad set of industries.

An ATP-funded project typically takes three to five years to complete. Because these projects are by design high risk and precompetitive, some will not succeed. Yet even when a project is highly successful, as Rosalie Ruegg, Director of the ATP's Economic Assessment Office (EAO), indicated in her remarks, the broad-based economic benefits from the innovation may not be apparent for a number of years after the project has ended. For some technologies, a decade or more may pass before these economic benefits are realized. By necessity, evaluation of the economic impacts of the ATP portfolio of R&D projects relies on near-term and intermediate indicators of the long-run economic benefits that go beyond those that are captured by the firm undertaking the initial R&D. In selected cases, where the technology is especially promising, we expect our analyses to include projections of future benefits.

On a routine basis, the EAO collects information on participating organizations for the duration of the ATP project and for six years after the project has ended. For each organization, the Business Reporting System (BRS) involves an initial baseline report, annual reports submitted during the life of the project, and a closeout report collected at the end of the project. For six years after the project has concluded, the EAO plans to conduct a series of follow-up interviews with the technical and business leads of the project in each ATP-funded organization and with their counterparts in other organizations that did not receive ATP funds but are now using the ATP-funded technology, pursuing specific applications of the technology, or building upon the ATP-funded technology in a related area.

From time to time, the EAO also conducts special studies that usually are carried out by independent researchers on a contract basis. These studies include statistical analyses involving comparisons with ATP awardees to enterprises that have not received any ATP funding, investigations of the factors that promote (or inhibit) spillovers in specific industries or technical areas, and in-depth case studies of specific projects or a group of related projects.

Pathways to Broad-Based Economic Benefits

In general, an ATP-funded project can achieve broad economic benefits by the direct introduction of a new product or service into the market, or by indirect means, through the take-up by other organizations of the knowledge and techniques that were developed during the project. Some ATP projects will proceed along the direct path, yielding benefits to consumers that are directly traceable to the project results. However, because the ATP selects only enabling, high-risk R&D projects for funding, it is expected that the indirect route will be important as well.

At the EAO, information is collected on the efforts of ATP-funded organizations to bring to market new products or services based directly on the ATP-supported technology. Information is also collected on the indirect pathways through which ATP-supported technologies achieve economic benefits. Another area of focus are the EAO's efforts to address the information requirements involved in tracking the progress of ATP-funded technologies that proceed to market via indirect pathways.

The results of an ATP-funded technology project take an indirect route to market when knowledge is passed from one firm to another, and in a series of such exchanges over time, the ATP-funded technology is altered, improved upon, or integrated with other technologies. Frequently, companies other than those supported by the ATP are involved after the project has ended. These companies may be involved in developing complementary technologies, carrying out additional R&D on the ATP-funded technology, or undertaking the final product development and marketing activities necessary to bring a commercially viable innovation to market. When (and if) the indirect route eventually yields such an innovation, the contribution of the ATP-funded R&D project may be only a distant memory to those finally responsible for bringing this innovation to market.

Without a research effort to follow these developments as they unfold, it will be difficult to determine the contribution that the ATP project has made. Hence, the EAO is planning to "follow" the technology in the post-project period, wherever it goes.

R&D Partnering and Information Sharing

The ATP supports innovative activity in a number of different technical fields and in a variety of industry contexts. How a firm organizes its partnering relationships, how it learns about relevant technical advances by other R&D organizations, and the ways in which it shares information (and how much it shares) with other companies vary by field and by industry. To evaluate the spillover benefits from ATP-funded R&D activities, information is needed about the variety of formal and informal cooperative organizational arrangements that are formed in ATP-funded projects and how these arrangements facilitate the innovation process.

Since 1993, the EAO has collected information through the BRS on both the formal and informal cooperative activities of organizations engaged in ATP-supported R&D projects. To date, the BRS data show that the vast majority of ATP-funded projects involve some degree of formal collaboration by a for-profit company with one or more of the following: another company, a university, a government laboratory, or other nonprofit organizations.

Knowledge spillovers and complementary technology developments are facilitated by interorganizational cooperation in R&D and by information sharing among companies with complementary technical capabilities. However, U.S. companies have had considerable difficulty in forming and sustaining cooperative R&D activities with other enterprises. Outside of ATP joint venture projects (and other government-supported consortia), most cooperative R&D ventures formed by companies are short-lived. Their short lives reflect the problems that U.S. companies experience in establishing the terms for sharing information among member firms, resolving disagreements over the division of property rights among participating firms, and in sustaining commitment of key members to the joint effort.

Preexisting consortia already have resolved these cooperation and coordination problems, and hence, ATP support is not viewed as critical to their formation. For funding decisions, the ATP views a preexisting consortium as a single entity. For example, in the *2mm* joint venture, a project of auto suppliers, producers, and universities designed to reduce dimensional variations, the Auto Body Consortium (ABC) was the lead organization. ABC counts as only one member of that joint venture. ATP support for joint venture activity is limited to the formation of new cooperating teams, made up of at least two for-profit organizations, for long-term (up to five years) R&D projects. The initiation of a new

R&D project by an existing group may be supported if the proposed joint venture also contains at least two separate for-profit organizations.

The ATP as a Catalyst to Cooperation

ATP funding has been instrumental in the formation of new cooperative arrangements in a number of technical and industry application areas. ATP-funded joint ventures vary in size (i.e., the number of separate organizations) and also in composition (i.e., the different types of organizations). In purpose, some joint ventures are system integration efforts, involving customer firms and their technology suppliers, as in the case of the various automobile manufacturing technology projects. Others, such as the project on printed-wiring-board technology, include rival producers focusing on a problem that is common to all of them. A third type is the venture in which separate companies combine their complementary technical expertise for the purpose of developing a new product or service. This is illustrated in the Spoken-Language Forms Translator for Information Transactions project, which was funded in 1998. Two small companies, Language System, Inc., and Eloquent Technology, Inc., are working together on a joint effort, combining one firm's expertise in speech recognition and speech synthesis with the other's specialization in language understanding and translation programs.

All three types of ATP-supported joint ventures are institutions designed to internalize at least part of the spillover benefits among the participant member organizations. In cases in which the membership includes lead users and technology developers, the take-up of the technology by the user organizations is expected to be faster than would occur in the absence of the joint venture. When the venture brings together complementary expertise in different fields, we expect that new products or process innovations based on these combined capabilities will be introduced sooner than if these firms had proceeded independently of one another. Moreover, to the extent that ATP support enhances a company's capability to collaborate with other organizations on R&D projects, we expect participating organizations to continue to form new collaborative ventures and to sustain the cooperative activities with their joint venture partners after the ATP project has ended.

Formal R&D partnering also may occur through subcontracting ties to other organizations. Subcontracting is a frequent form of R&D partnering employed by companies having a single-company award from the ATP. Most projects involve subcontracting relationships. The EAO collects information on the division of responsibilities between principals and subcontractors on ATP-funded projects. We also plan to collect additional information on these relationships in future studies.

Informal partnering and information-sharing arrangements are difficult to measure. However, the EAO attempts to do so by collecting information on a number of indicators of informal cooperation. An ATP-funded company may form one or more alliances with other companies that are not direct participants in the project. These alliances may involve potential customers, or involve companies with complementary technical or business expertise. In addition, all ATP award recipients report on the papers published by scientists and engineers, and provide data on patent applications and awards related to the ATP project. When the papers involve coauthoring by scientists and engineers with different organizational affiliations, we consider this to be an indicator of interorganizational cooperation in R&D activities. Joint patenting activity that includes an ATP-funded company and another organization is another indicator of cooperation that can be measured independently of the formal partnering arrangements reported as a subcontract, a joint venture, or an informal alliance. Similarly, conference presentations are a form of information sharing. The BRS also includes data on the conference presentations given by scientists who are working on ATP-supported R&D projects.

Post-project: Handoffs, Acquisitions, and Spinoffs

An ATP-funded technology that travels an indirect pathway to market frequently involves post-project advances in other, complementary technological developments that may be undertaken by the company initiating the project or by organizations other than the company responsible for carrying out the initial R&D project. In either case, the complementary technologies are not funded by the ATP, but are important to the technology that was developed with ATP support. In the post-project data collection effort, the EAO plans to collect information on these complementary technologies and the organizations responsible for their development.

In the BRS, we currently collect information on the awardee's plans, tracking the number and types of specific applications. Our post-project data collection effort is designed to follow the advances in specific short-term and long-term application areas that the management of the innovating firm considers important. In the postproject data collection effort, we also plan to collect information on the number of new applications and to identify those applications that no longer are being pursued by the company or any other organization.

With respect to the take-up of ATP-funded technologies by other firms, the EAO staff and its contractors have identified a number of important mechanisms by which technology transfer occurs across organizations. Some companies in ATP projects focus only on R&D and depend on the product development and commercialization activities of other enterprises. The commercialization strategy of such an R&D contractor organization is usually to license the technology to another enterprise. This type of innovating company captures only a small share of the economic value of the technology in the revenues that it receives from the sale of licenses and other property rights that it holds on the technology.

The post-project data collection effort is designed to collect information on the revenues that these companies earn from these sources. With this handoff of the technology from one company to another, the realization of broader economic benefits depends on the success of the partnering firm in commercializing the technology. The post-project information-gathering effort also includes a systematic follow up of the commercialization activities of these partners.

Another way in which technology is transferred from one organization to another is through an acquisition. Owners of small R&D companies may view the acquisition of their firm by another company as a desirable exit strategy. The contribution of the ATP-funded technology development project to the value of the firm being acquired is a post-project indicator of a short-term economic benefit. Over the longer term, the achievement of broad-based economic benefits from the ATP-funded technology depends on what the acquiring company does with the technology. Hence, the post-project data collection effort of the EAO is designed to track developments by the acquiring firm in using or developing technologies that are related to the technology funded by ATP.

Acquisitions are also the result of business failures. From the point of view of the ATP, the failure of the initial innovating firm does not necessarily signal the end of the technology's development path. In the EAO-sponsored study on the first 38 completed ATP-funded projects, a few small companies went out of business after the project ended. However, in at least one case, another enterprise acquired the business and the rights to the technology developed with ATP support. If the acquiring firm develops and brings to market technologies related to the ATP project, then the social benefits from the ATP's investment may be positive, even though the funded company was unable to reap much, if any, of that benefit. Hence, the post-project data collection effort is designed to distinguish between cases in which the technology "lives" but the firm "dies" and cases in which both the technology and the firm "die" together.

Last, a technology also can change hands when a larger company spins off a unit for the purpose of developing a new product or market. When this occurs, the EAO plans to follow the progress of the spinoff unit, rather than the parent organization.

Concluding Remarks

The goal of the ATP is to support the development of technologies with the potential for broad-based economic benefits. If the ATP is making appropriate project selection, the value that is captured by the innovating firm is only a small part of the potential economic benefit from the technology. In the extreme case, an ATP-funded company may cease to exist and derive little or no direct benefit from its R&D activities. Yet, the ATP-supported technology may live on through the activities of other firms (e.g., a customer, competitor, or firm that has acquired rights to the technology for use in another industry). Even though the firm responsible for carrying out the initial R&D project may benefit very little, the project still may have a large economic impact through some spillover mechanism. The EAO post-project evaluation effort is designed to follow the technology in order to trace the economic benefits in the medium term that are associated with the post-ATP project development of the technology, whether or not the awardee is the organization pursuing it. Wherever possible, the post-project data collection effort of the EAO also will track developments in related technologies that are complementary to, or otherwise build upon, the ATP-funded technology.

In its evaluation studies, the ATP is committed to protecting the confidentiality of the proprietary information that companies provide us through the BRS and other special studies. This protection is compatible with our use of these data in statistical analyses to assess the economic impact of the ATP portfolio. Moreover, as a result of its evaluation research efforts, the EAO is in the process of compiling a unique database on private-sector research, technology development, and commercialization activities. For large and small companies alike across a broad spectrum of technical fields and industries, the information we are collecting tracks R&D projects from their inception to their conclusion and beyond. The resulting database will surpass all other existing databases in its level of detail on each project, the breadth of private-sector R&D activities covered, its inclusion of both successful and unsuccessful cases, and its panel quality (i.e., multiple measures of the activities of the same organizations and specific technologies that are taken repeatedly over an 8- to 11-year period).

In the long run, analyses of these data should increase our understanding of the factors affecting the ATP's success. In addition, future policy makers will benefit from the research that we are conducting now on the ways in which public–private partnering arrangements facilitate the development of technologies and how the resulting R&D activities bring about broad-based economic benefits. Finally, our research also should shed light on the nation's innovation system, especially in providing a more detailed map of the pathways through which technological change contributes to economic growth and to the productivity increases necessary to sustain and improve the standard of living of Americans in the next century.

ASSESSING PRODUCTIVITY IMPACTS IN HEALTH CARE INFORMATION

William Lehr
Columbia University

Dr. Lehr said that the research he would discuss was conducted jointly with his colleague at Columbia, Dr. Frank Lichtenburg. The research has examined several projects in ATP's focused program on the use of information technology in the health care sector. The motivation for the research was the so-called productivity paradox, in which investments in information technology that seem intuitively to have productivity-enhancing potential do not appear to pay off in terms of higher productivity. Dr. Lehr said the paradox was summarized in Robert Solow's quip that "we see computers everywhere except in the productivity statistics." With productivity growth on the rise again, the paradox has received less attention, even if its roots remain imperfectly understood.

Dr. Lehr said that both he and Dr. Lichtenburg believe that information technology was improving productivity in health care, but that better data needed to be assembled in order to make the case. Drs. Lehr and Lichtenburg also believed that integrating case studies into empirical research would be a useful strategy to addressing the productivity issue. For today's session, Dr. Lehr said that he would discuss one case study from the ATP and preliminary results from their empirical work.

Dr. Lehr described two categories in which investments in information technology could pay off in health care:

- *Improved quality of care:* Doctors may have better information, make faster decisions, and prescribe drugs more appropriate to the diagnosis.
- *Lower costs:* Health care delivery has very high administrative costs and, at least in principle, information technology can help lower these costs.

The latter category is easier to measure than the former, but both are challenging, Dr. Lehr said. A criterion for selecting case studies for the research was to look for projects on which Lehr and Lichtenburg could obtain the necessary information.

Empirical Analysis

For the empirical work, the basic idea was to find or develop a measure of the quality of health care, and that this is depends on a variety of things. In past econometric work, economists used tax rates, existence of various kinds of health insurance plans (e.g., prospective payment plans) to measure quality. Lehr and Lichtenburg have tried to include investment in information technology as an explanatory variable.

Lehr and Lichtenburg combined a data set on hospitals that has measures of the quality of hospitals with data from a hospital accreditation body on best practices in use of information technology. Although the data on hospital quality cover 15 to 20 states, only Iowa was used for their first cut at estimation; thus the data set contained only 24 observations.

From this, they were able to estimate the impact of information technology on health care quality while controlling for other factors that influence health care quality. Even with the very small sample, meaning that the results should only be considered suggestive, Lehr and Lichtenburg found that investment in information technology contributed to improvements in health care quality.

Case Studies

Lehr and Lichtenburg believe that case studies can yield a richer sense of the private and social returns to information technology investments in health care. Dr. Lehr noted that the information from the case studies can only be prospective, that is, the potential benefits are being examined early in investment cycle; one cannot expect benefits to show up until several years have passed. The kinds of questions that Lehr and Lichtenburg asked were whether ATP grants were used for purposes consistent with the ATP's goals, and how ATP's selection process could be improved.

Lehr and Lichtenburg looked at two companies: Instream, a Massachusetts company developing electronic commerce solutions for hospitals; and Sunquest, a company developing alert systems, in which pagers transmit information to doctors about patients' conditions.

The Instream Case

Dr. Lehr described Instream as a company developing electronic commerce products for behavioral health care companies (e.g., psychiatric services) and their provider networks. In the behavioral health care field, as throughout the entire industry, it is becoming more challenging to administer health care delivery among a network of dispersed providers. Much of this has to do with information burdens, which are increasing because of things such as liability. To address this, Instream proposed to develop "smart forms" to automate the communication between health care providers and administrators of insurance plans. Smart forms would be built using an open architecture so that the wide variety of electronic forms used by various health care providers could be readable on any computer system. This was largely an integrative project, and used no new technology. Indeed, it would be easy to argue that Instream was doing something that some company would have done soon anyway. In funding Instream, the ATP was accelerating the deployment of a certain technology in a particular health care sector, that is, behavioral health.

The benefits were clear, in that the electronic commerce approach supplanted a system by which faxes and phone calls carried out the communication tasks, while reducing the opportunity for errors in, for example, keying in patient identification numbers.

Lehr and Lichtenburg then estimated the savings from the Instream technology that users could expect. With respect to administrative costs, the electronic commerce solution saved 22 percent on administrative expenses. For the administrator of the health care plan, operating margins were estimated to increase by

140 percent. For Instream's customers, cost savings were estimated to be $10 million per year; Instream received $1.37 million from ATP to develop this technology. The expected internal rate of return, concluded Dr. Lehr, was approximately 95 percent.

Ironically, Instream failed in 1998, showing how risky these projects can be. The company expanded into on-line content, which proved more costly than anticipated, and eventually resulted in a cash-flow squeeze that proved too severe. One clear long-term benefit, even though Instream failed, is learning spillovers. There are now approximately 150 companies in this sector, but Instream was among the first. The later entrants learned a great deal about the market from Instream's experience and, moreover, Instream's technology is still "on the radar screen" in the industry.

In terms of broader lessons learned, Dr. Lehr said:

- ATP funding leverages private capital. Instream received venture capital and ATP funding helped to attract it.
- Technical industry expertise was acquired. Instream gained expertise, but the Instream grant was part of a broader ATP-focused program. This provided some scale among other actors in the industry, and thus an incentive for them to invest in these technologies. Because the ATP held conferences around the focused program, there were opportunities for industry players to network.
- As a technology integration project, as opposed to development, there was no technology waiting to be picked up by others when Instream failed. However, there were spillover benefits because Instream proved that the technology could work, and left a network of users that followers could, and did, exploit.

COMPARING ATP AND NON-ATP RESEARCH JOINT VENTURES

Nicholas Vonortas
George Washington University

Dr. Vonortas described the research project that he conducted for the ATP, which investigated research joint ventures at the ATP. The notion behind his work was to look at the performance of ATP-funded joint ventures from 1990 to 1995 as compared to joint ventures not funded by ATP in the same period. Dr. Vonortas and his colleagues at George Washington developed a database of research joint ventures using filings from the Department of Justice (DoJ) and other data describing the financial performance of firms in joint ventures. The database also included joint ventures not from DoJ because not all joint ventures register with DoJ. In total, Dr. Vonortas had information on 102 ATP-funded joint ventures and 510 joint ventures that did not receive ATP funding.

The objective of his research was to go beyond the traditional economic literature on joint ventures, which Dr. Vonortas does not find fully satisfactory. The literature argues that firms—typically large ones—enter into joint ventures to "diversify virtually." In addition to econometric analysis, Dr. Vonortas and his colleagues conducted case studies on ATP joint ventures, including one on Genometrix.

Comparing Performance of Joint Ventures with Non-Joint Ventures

Turning to his data and results, Dr. Vonortas pointed out that the number of ATP grants to joint ventures has grown noticeably since 1994 and 1995; this increase coincides with the start of focused programs at the ATP. In terms of technologies, there is no difference in the distribution of technology areas pursued by ATP joint ventures versus non-ATP joint ventures. This, said Dr. Vonortas, should be considered a good thing.

For his analysis, Dr. Vonortas used a control group of firms that had never participated in *any* joint venture. This creates three groups: ATP joint ventures, non-ATP joint ventures, and non-joint venture participants. He found that there are significant differences among firms that have never participated in a joint venture and firms that have been in joint ventures (irrespective of whether it was an ATP or a non-ATP joint venture). In focusing on firm growth, non-joint venture participants seem driven strongly by the history of profitability, something that is not the case for joint venture participants.

Turning to evaluation, Dr. Vonortas emphasized that the case studies are important supplements to empirical work. Interviewing company officials for his case studies opened up new avenues for research for Dr. Vonortas and, had he not done case studies, he would have concluded that the ATP joint venture project had failed. In summing up, Dr. Vonortas urged researchers to use case studies as a way to gain deeper understanding of the ATP and the individual projects.

QUESTIONS FROM THE AUDIENCE

Egon Wolff of Caterpillar, Inc., observed that a benefit from the ATP—indeed a spillover—is that it has taught U.S. companies how to collaborate. Prior to the ATP, U.S. companies had some experience with collaboration in large programs such as SEMATECH, but the ATP encouraged collaboration more broadly. With respect to spillovers from R&D investment, approximately 70 percent of Caterpillar's R&D investment ends up in small companies and universities. The dissemination of knowledge is ongoing for Caterpillar's ATP projects when R&D funding is channeled through other firms.

Reflecting on R&D project approval at Caterpillar, Mr. Wolff said that it is probably as difficult to gain approval for a R&D project at Caterpillar as it is to obtain venture capital financing. He also said that he felt that the benefit of outside review of R&D proposals, as done in ATP, is enormous. Caterpillar would benefit, Mr. Wolff believed, from having roughly 30 percent of its R&D budget subject to external review.

Steve Isaac from IBC Advanced Technologies made an observation about intellectual property protection. From the perspective of a company that has received ATP grants as a single applicant, he said that strong intellectual property protection is an important incentive to participation in the program. Even with strong intellectual property rights, an ATP award is a "sparkplug to get his company motivated" to invest its own resources in a particular project. To apply, his company must have a clear commercial use in sight when undertaking a grant, which eventually places the technology in the commercial arena.

If a company does not commercialize, Mr. Isaac continued, there are a number of actions that can be taken that will move the technology eventually into the public domain. At one end of the spectrum, the government can exercise "march-in rights" on publicly funded technology that is not used by a company, and essentially seize it from the company. This is an extreme measure, which is rarely, if ever, used. Alternatively, if a technology is not commercialized because the company fails, that technology is bound to be sold in the process of dismantling the firm. Mr. Isaac also noted that the market will recognize a good technology, and it is likely to find it if it has commercial potential.

In response to Mr. Isaac's observations, Dr. Kelley said that a study that the ATP has under way looks at how firms across different sectors protect intellectual property. Patents may be important in some sectors, less so in others. Similarly, cooperation may promote spillovers in some sectors more so than in others. The ATP is working to understand these differences across sectors.

In summarizing, Dr. Cockburn said that there are circumstances under which publicly funded R&D is licensed on a nonexclusive basis, and that there is no shortage of venture capital firms seeking to license good ideas funded by public R&D programs. With respect to cooperation, Dr. Cockburn said that, at least today in the United States, there seems to be plenty of momentum to cooperate. And there is a well-developed infrastructure of lawyers and business consultants to put joint ventures together. The question of which joint ventures work and which do not remains open. On patent protection, Dr. Cockburn said that many companies have a "use it or lose it" provision in their patent laws; if, after five or seven years of patent protection, a company does not use the idea, it loses its patent.

Panel VI:
Observations and Policy Issues

INTRODUCTION

Charles Wessner
National Research Council

Dr. Wessner convened the day's final session by saying that the panel offered the opportunity for unstructured discussion about the Advanced Technology Program (ATP). Dr. Wessner opened the discussion by asking management of the ATP about the trade-off between devoting resources to making new ATP grants versus spending time and money on assessing past grants. Dr. Rosalie Ruegg responded by saying that the ATP does not do detailed case studies on each project, but focuses rather on cases of special interest. Through the National Bureau of Economic Research, the ATP also teams with other researchers, such as Josh Lerner from Harvard, as a cost-effective way to obtain high-quality assessment of the program. The vast majority of ATP funds go to grants for companies, with a small portion going to assessment.

ATP ASSESSMENT: LOOKING BACK AND LOOKING AHEAD

Barry Bozeman
Georgia Institute of Technology

Dr. Bozeman's comments on ATP assessment looked past assessments of other programs, and made observations about ATP assessment in the future.

Dr. Bozeman recalled an earlier statement about the ATP being the most studied federal program since Head Start. Taking issue with that characterization, Dr. Bozeman said that most social programs are assessed a great deal, probably more so than the ATP. Nonetheless, Dr. Bozeman said that this was a good metaphor for thinking about the challenges facing the ATP.

Dr. Bozeman agreed, however, that the ATP has been studied more than any other technology program. The ongoing ATP assessment has benefited from the development of a number of useful assessment tools. Having read many of the studies on the ATP, Dr. Bozeman said he has found most of them to be well-done and valuable contributions to program assessment. In today's environment in which the Government Performance Review Act (GPRA) is so important, this is no small accomplishment.

Another metaphor from Head Start is that the best studies show that the Head Start program did not work very well. The more precise the studies were, the smaller the "trace effects" of Head Start were, that is, the effect of Head Start quickly wore off for the individuals studied. One lesson of Head Start is to learn from evaluation. Because of Head Start evaluation, another program was developed to address diminishing trace effects and this greatly improved the Head Start program. Dr. Bozeman said that he was pleased to see that the ATP was using its evaluation to improve program implementation.

Turning to another Head Start metaphor, Dr. Bozeman said that, in looking back to the old Office of Economic Opportunity and other War on Poverty programs, he doubted that many people would recall which one had the best cost/benefit ratio and the best rate of return to the economy. The program with the best return was not Head Start, but the Job Corps program. Yet in spite of positive assessments, Congress disliked the Job Corps and the program did not have a long life. The lesson for the ATP is that, regardless of whether returns to the economy are estimated at $20 million or $35 billion, these positive evaluations in themselves are not likely to be program sustaining.

Dr. Bozeman said that this realization can be quite liberating. It gives program managers a chance to build a clientele for what really works. He sees this already in the ATP; in addition to estimating economic benefits, Dr. Bozeman said that evaluators are paying attention to program instruments that are effective and are highlighting them.

One of the most important metaphors from programs such Head Start is that, overall, the War on Poverty was lost. That, at least, was the prevailing perception in the 1970s, said Dr. Bozeman. However, an authoritative study from the University of Arizona found that, taken over a long time horizon, the returns from the War on Poverty were quite substantially positive, especially in light of the modest amounts invested. Dr. Bozeman said that this would be the likely long-term conclusion on the ATP, namely, that its benefits would be shown to be quite positive. In concluding, Dr. Bozeman said that he hoped there would be an opportunity for this kind of long-term analysis of the ATP.

THE ATP AND LEGISLATIVE FLEXIBILITY

James Turner
House Committee on Science

Mr. Turner said that, in the day's discussion, "a convincing case . . . has been made that this program [ATP] really has done some good." Clearly, there are companies in existence doing valuable research that would not have existed without the ATP. And there are excellent research outcomes from existing companies or groups of companies that would not have come about without the ATP.

Another overarching fact about the ATP is that it exists in a very political environment; evaluation should take that into account. Mr. Turner said that he does not want to be at a symposium 25 years from now in which a researcher says that the ATP, a program canceled 20 years ago, did great things. Mr. Turner would like to convince ATP's critics of ATP's strengths, so that it is not subject to attack the next time a Republican is in the White House.

Mr. Turner also responded to several comments during the day that the ATP statute was "fuzzy" and was not prescriptive enough. Mr. Turner said that this was intentional. The House Committee on Science has a long relationship with the National Institute of Standards and Technology (NIST), and the Committee knows that NIST has a tremendous amount of expertise that the Committee lacks. In building a new program such as the ATP, NIST's expertise was seen as something that justified writing flexibility into the statute.

Finally, Mr. Turner said that he hoped that the evaluation tools developed for the ATP could be used to assess other technology programs. This was increasingly important in the GPRA environment. Evaluation of technology programs is more important today than in the past, and researchers can do a great service by adapting tools from the ATP to other programs.

THE ATP AND U.S. TECHNOLOGY POLICY

Richard Nelson
Columbia University

Reflecting on how the ATP fits into a broader structure of U.S. technology policy, Dr. Nelson said that the ATP plays an important niche role. It is a program that can accomplish valuable things under certain circumstances, but should not be seen as a general-purpose instrument for technology policy. Dr. Nelson identified three dimensions of the ATP that he sees as constituting its niche:

- *The locus of research activities*: Research and development (R&D) in the United States takes place in universities, government labs, special-purpose organizations such as SEMATECH, and industry. The ATP is clearly oriented toward providing resources for R&D in industry.

- *The role of industry in molding the allocation of R&D resources*: For any U.S. technology program, it is important to have business closely involved in setting R&D priorities. This can be done through advisory committees, through special commissions, or by having business pay a portion of the cost of government-sponsored R&D. The ATP uses the latter approach, which is appropriate for many R&D activities.
- *The balance of benefits accruing to the organization performing the research versus the benefits that are distributed widely to the public*: The ATP, Dr. Nelson said, funds R&D in which a "nontrivial portion of research benefits go private."

In commenting on the ATP's role in technology policy, Dr. Nelson said that there are many areas in which the ATP is the appropriate instrument for meeting public goals, but he cautioned that there may be areas in which the ATP is not the appropriate instrument.

THE ATP AND PROGRAM MANAGEMENT

J. C. Spender
New York Institute of Technology

Dr. Spender said that today's discussion reminded him of Dr. Nelson's book, co-authored with Sidney Winter, *An Evolutionary Theory of Economic Change*, in which Nelson and Winter highlighted the search for organizational routines to meet certain goals. In talking about the ATP, Dr. Spender observed that much of the focus on "program instrumentalities" was really about the search for the appropriate routines to manage the ATP. There were three elements of this search:

- *Determination of policy*: Are the routines that have been developed in the ATP over several years appropriate to all programs, or just to ATP?
- *Constraints*: Are the practices developed in the ATP effectively constrained, through things such as requiring matching funds or encouraging joint ventures? Do these constraints affect the measures of program impact?
- *Achieving objectives*: Is the ATP about spillovers? Or are there other objectives?

The ATP's objectives remain ambiguous, even after the day's discussions, and Dr. Spender recommended considering the interaction of the public and the private to think this issue through. The history of Silicon Valley, Dr. Spender argued, is about the privatization of public goods, goods that were developed using defense contracts. The ATP, in contrast, seemed to encourage the "publicization" of private R&D expertise.

The interplay between public and private is the heart of the ATP, and Dr. Spender argued that, to understand this interplay, economic data need to be supplemented with sociological and anthropological data. Case studies could address these issues, but the question then becomes how to interpret case studies. One lens through which case studies could be viewed is the notion of "communities of practice." An industry or a firm may be seen as a community of practice and the ATP is a mechanism that affects this community. Another term for a community of practice might be the innovation system. There must be greater effort devoted to modeling these complex innovation systems, recognizing the interdisciplinary nature of the task.

THE ATP AND SPILLOVERS

Christopher Hill
George Mason University

Dr. Hill of George Mason University observed that the Senate staff most closely involved in the creation of the ATP did not view it as a solution to all of America's economic ills. Rather, the ATP was seen as an experiment, an opportunity to apply some policy prescriptions that had been talked about for years. Conceived as a program modest in size, it was originally intended to focus on computers, biotechnology, and robotics. A clause was inserted into the legislation to provide an "open window" for the program to address subject areas beyond those three. This "open window" has allowed the ATP to pursue exciting new areas and respond to changing economic and technological challenges.

In reflecting on the modest scope of the ATP, Dr. Hill said that he contributed a paper to Lewis Branscomb's book, *Investing in Innovation,* that spent a great deal of time considering other possible technology policy instruments in the event that the ATP proved insufficient. Dr. Hill therefore agreed with Dr. Nelson that the ATP should be seen as one part of a broader technology policy.

Dr. Hill then proceeded to try to reframe the externalities and spillover issue. Taking the National Science Foundation (NSF) as an example, Dr. Hill said that nearly everyone is comfortable with what that agency does. As a grant-giving organization, NSF provides a mixture of public and private goods. Faculty members and students at universities receive NSF funds, and this creates goods that recipients can capture privately. Faculty members generate research, which will reflect positively on them when their performance is reviewed, and graduate students receive credentials and training for the job market. Because he received NSF funding as a graduate student, Dr. Hill has been able to enjoy a higher level of income than he would have otherwise. Dr. Hill also pointed out that NSF induced him to participate in its program at a low cost; in 1968, when he was in graduate school, his NSF stipend of $213 per month was enough to support him in school for four years. However modest the stipend, it accomplished a public purpose, namely to create a more scientifically and technically trained workforce. One can argue, that the founders of NSF really did not care about his personal success or that of other award recipients. However, he and others were instruments of public policy, not the ends of public policy. As long as he and others like him created appropriate knowledge spillovers, their individual success was irrelevant to NSF.

Dr. Hill argued that the ATP is in an analogous situation. It is trying to induce private companies to engage in behavior that has a public purpose. If it were only for private purposes, in his view there would be no justification for the ATP. The ATP tries to do this by giving firms the minimum amount of money to induce them to engage in R&D that they otherwise would not undertake. It does not matter, argued Dr. Hill, whether the firms succeed or not. From the perspective of the program's goals, it does not matter whether awardees succeed or fail. All the ATP wants the companies to do is develop new knowledge and new technologies. To carry that out, it is helpful for those companies to succeed and continue to exist. Moreover, he added that there is the political consideration that "it is not good politics to fund companies and then have them go belly up."

The real goal, then, is to generate the spillovers to society, not create profits for private firms. For these reasons, Dr. Hill said that ATP evaluation should pay little attention to its awardees client companies and instead should focus on the spillovers that do not accrue to the awardees.

QUESTIONS FROM THE AUDIENCE

Todd Watkins from Lehigh University said that one of the benefits of programs such as the ATP was the social aspect of communities of practice, or what economists call "social capital." These are the benefits associated with collaborative activities and people in industries being able to work with one another easily. Dr. Watkins asked whether assessment of the ATP considered social capital or communities of practice not only among successful ATP firms, but among those that have not won awards. Dr. Watkins noted that the mere process of coming together to apply for an ATP award may yield significant benefits in terms of social capital. In response, Dr. Maryellen Kelley of NIST said that ATP assessment does try to include the social capital benefits of the program.

Dr. Wessner observed that many venture capitalists say that there are many more attractive business ideas to be funded than there is venture capital available to fund them. Dr. Wessner asked NIST Director Ray Kammer if that was the case with this program. In response, Mr. Kammer said that ATP funds approximately 1 out of every 10 proposals it receives. If it had unlimited funds, the ATP would like to fund between 2 and 3 out of every 10. At the present level, the ATP funds about 10 percent of its applicants, and somewhat more than 20 percent of applications are worthy of funds. Mr. Kammer added that the number of applications is also a function of how much money the ATP receives in its appropriation. When the program budget is expanded, it tends to receive a greater number of applications.

Dr. William Long expressed disagreement with Dr. Hill's statement about whether we should care about the health of companies funded by the ATP. Dr. Long said that if an ATP grant recipient does not produce a good or service, it is difficult for the ATP-funded technology to be disseminated in the economy. In response, Dr. Hill clarified by saying that ATP companies do not need to do better than their counterparts in a sector in order for spillovers to be created. Dr. Long added that it is difficult to have spillover effects if there are no products in the market.

CONCLUDING REMARKS

In concluding the panel, Dr. Wessner recalled the introductory remarks of Bill Spencer, noting that the ATP, like other government–industry partnerships, can be seen as an experiment. These experiments have a long history in the United States, dating at least to congressional funding for the telegraph in the mid-nineteenth century. He added that it seems that we do more experimenting in government–industry partnerships in the United States than we are politically or ideologically willing to admit.

Dr. Wessner also observed that there was little discussion about activities of other countries in programs such as the ATP. As Dr. Spencer had reminded us at the outset, in other countries, there is little debate over whether government should support industry in technology development; many countries implement substantial programs as a matter of course. As an example, he cited a recent conversation with an American venture capitalist who was concerned that the German government's growing support for its biotechnology industry in the form of very patient capital could pose a challenge to the leading position of U.S. industry. Finally, Dr. Wessner added that although foreign partnership programs face less scrutiny, they perhaps do not benefit from the rigorous assessments that characterize some U.S. programs.

With respect to the assessment of the ATP, Dr. Wessner said that, not every agency would invite this type of open discussion with program advocates and opponents, program users, and program researchers. The fact that this type of meeting was sought is much to the credit of the NIST management. The fact that the senior management from the ATP and NIST stayed for the entire event underscored their interest in hearing outside views on the operation of the program. It is to be hoped that more agencies would invite this type of objective assessment.

In closing, Dr. Wessner reminded the audience that government support to industry, and questions about the appropriateness of that support, have a long history in the United States dating back to the origins of the Republic. Alexander Hamilton's 1791 *Report on Manufacturers* had stressed the importance of developing new forms of manufacturing and the government's positive role. As a strong proponent of government support for new industries, Hamilton had affirmed that "there is no purpose to which public money can be more beneficially applied than to the acquisition of a new and useful branch of industry, no consideration more valuable than a permanent addition to the stock of productive labor."

With this early federalist observation in mind, Dr. Wessner thanked the participants for bringing their expertise and experience to this initial review of the Advanced Technology Program. He added that the Board expected this symposium to contribute both to our understanding of the ATP and importantly, to the Board's overall review of government-industry partnerships. It is anticipated that, in cooperation with NIST, additional analysis of the ATP will be carried out under the auspices of the Government-Industry Partnerships project. In this second phase, we will draw both on the ATP's well-developed program of assessment and outside researchers, as well as the experiences of award recipients, to identify program strengths and potential improvements. Once this additional analysis is completed, the project steering committee expects to develop specific findings and recommendations for the Advanced Technology Program. These will be reported separately and will also be an important contribution to the Academies' broader review of government-industry partnerships.

Annex A: Bibliography

Alic, John; Branscomb, Lewis; Brooks, Harvey; Carter, Ashton; Epstein, Gerald, 1992. *Beyond Spinoff: Military and Civilian Technologies in a Changing World.* Boston: Harvard University Press.

Baily, M. and Chakrabarti A., 1998. *Innovation and the Productivity Crisis.* The Brookings Institution, Washington, D.C.

Barfield, C. and Schambra, W., eds., 1986. *The Politics of Industrial Policy.* Washington, D.C.: American Enterprise Institute for Public Policy Research.

Brander, J.A. and Spencer, B. J., 1983. "International R&D Rivalry and Industrial Strategy," *Review of Economic Studies,* vol. 50, pp. 707-722.

Brander, J.A. and Spencer, B. J., 1985. "Export Subsidies and International Market Share Rivalry," *Journal of International Economics*, vol. 16, pp. 83-100.

Branscomb, L. and J. Keller, 1998. *Investing in Innovation: Creating a Research and Innovation Policy.* Cambridge, Mass., MIT Press.

Brown, G. and Turner J., 1999. "Reworking the Federal Role in Small Business Research," *Issues in Science and Technology,* vol. XV, no. 4, Summer.

Brown, M., 1995. *Impacts of National Technology Programs*. Paris: OECD.

Burroughs, J., 1993, "AMTEX—An Exciting Vision of the Future," *American Textiles International,* May.

Chang, Connie K.N., 1998. "A New Lexicon and Framework for Analyzing the Internal Structures of the U.S. ATP and Its Analogues Around the World." *The Journal of Technology Transfer*. vol. 23(2):67-73.

Chang, Connie K.N., 1998. *ATP Eligibility Criteria for U.S. Subsidiaries of Foreign-owned Companies: Legislation, Implementation, and Results*. NISTIR 6099 - January 1998.

Coburn, C. and Bergland, D., 1995. *Partnerships: A Compendium of State and Federal Cooperative Technology Programs*. Columbus, OH: Battelle.

Cohen, L., 1998 "Dual-use and the Technology Reinvestment Project." in Branscomb and Keller, *Investing in Innovation: Creating a Research and Innovation Policy.* Cambridge, Mass., MIT Press. pp. 174-193.

Cohen, L. R., and R. G. Noll. 1991. *The Technology Pork Barrel.* Washington, D.C.: The Brookings Institution.

CONSAD Research Corporation, 1997. *Advanced Technology Program Case Study: The*

Council of Economic Advisers, 1995. *Supporting Research and Development to Promote Economic Growth: The Federal Government's Role.* Washington, D.C.

Development of Advanced Technologies and Systems for Controlling Dimensional Variation in Automobile Body Manufacturing. NIST GCR 97-709, March.

Dixit, A.K. and Kyle, A.S., 1985. "The Use of Protection and Subsidies for Entry Promotion and Deterence," *American Economic Review,* vol. 75, pp. 139-152.

Fallows, J. 1994. *Looking into the Sun: The Rise of the New East Asian Economic and Political System*. New York: Pantheon Books.

Flamm, K., 1996. *Mismanaged Trade? Strategic Policy and the Semiconductor Industry.* The Brookings Institution, Washington, D.C., 1996.

Flamm, K., 1988. *Creating the Computer*. Washington, DC: The Brookings Institution, 1988

Graham, O. L. 1992. *Losing Time: The Industrial Policy Debate*. Cambridge, Mass.: Harvard University Press.

Griliches, Z., 1990. *The Search for R&D Spillovers.* Harvard University, Cambridge, Mass.

Grindley, P., Mowery, D., and Silverman, B. 1994. "SEMATECH and Collaborative Research: Lessons in the Design of High-Technology Consortia." *Journal of Policy Analysis and Management*. Vol. 14 No. 4. 723-758.

Grossman, G., and E. Helpman. 1993. *Innovation and Growth in the Global Economy*. Cambridge, Mass.: MIT Press.

Hill, C., 1998. "The Advanced Technology Program: opportunities for enhancement," in Lewis Branscomb and James Keller, eds. *Investing in Innovation: Creating a Research and Innovation Policy.* Cambridge, Mass., MIT Press. pp. 143-173.

Horrigan, J., 1999. Cooperating Competitors: A Comparison of MCC and SEMATECH. Monograph. National Research Council, Washington, D.C.

Jaffe, Adam B, 1996. *Economic Analysis of Research Spillovers: Implications for the Advanced Technology Program*. NIST GCR 97-708. December.

Johnson C., 1982. *MITI and the Japanese Miracle: The Growth of Industrial Policy 1925-1975.* Stanford University Press, Stanford, California.

Kelley, Maryellen R., 1997. "Mission to Commercial Orientation: Perils and Possibilities for Federal Industrial Technology Policy," *Economic Development Quarterly*, vol. 11, No. 4: 313-328.

Kleinman, D. L., 1995. *Politics on the Endless Frontier: Postwar Research Policy in the United States*. Durham, NC: Duke University Press.

Krugman, P., 1990. *Rethinking International Trade*. Cambridge, Mass.: MIT Press.

Krugman, P., 1991. *Geography and Trade,* Cambridge, Mass., MIT Press.

Krugman, P., 1994. *Peddling Prosperity.* New York: W.W. Norton Press, New York.

Krugman, P. and Obstfeldt M., 1994. *International Economics: Theory and Policy.* 3rd Edition. New York.

Laidlaw, F., 1997. *Acceleration of Technology Development by the Advanced Technology Program: The Experience of 28 Projects Funded in 1991*. NISTIR 6047. October.

Lebow, I., 1995. *Information Highways and Byways: From the Telegraph to the 21st Century*. New York: Institute of Electrical and Electronic Engineering.

Lerner, J., 1999. "Public venture capital: rationales and evaluation." In *The SBIR Program: Challenges and Opportunities*. Washington, D.C.: National Academy Press.

Link, A. N., 1997. *The Advanced Technology Program Case Study: Early Stage Impacts of the Printed Wiring Board Joint Venture, Assessed at Project End.* NIST GCR 97-722, November.

Link, A. N., 1998. "Public/Private Partnerships as a Tool to Support Industrial R&D: Experiences in the United States." Paper prepared for the working group on Innovation and Technology Policy of the OECD Committee for Science and Technology Policy, Paris.

Long, W.F., 1999. "Performance of completed projects: Status report number 1" Washington, D.C.: U.S. Department of Commerce, NIST Special Publication 950.

Malone, T., 1995. *The Microprocessor: A Biography.* Hamburg, Germany: Springer Verlag/Telos.

Mansfield, E., 1996. *Estimating Social and Private Returns from Innovations Based on the Advanced Technology Program: Problems and Opportunities*. Unpublished report.

Mansfield, E., 1991. "Academic Research and Industrial Innovation," *Research Policy,* February.

McCartney, S., 1999. *ENIAC: The Triumphs and Tragedies of the World's First Computer*. New York: Walker and Company.

McCraw, T., 1986. "Mercantilism and the market: antecedents of American industrial policy," in Barfield, C. and Schambra, W., eds., *The Politics of Industrial Policy.* Washington, D.C.: American Enterprise Institute for Public Policy Research.

Mowery, D. ed. (1999) *U.S. Industry in 2000: Studies in Competitive Performance*. Washington, D.C.: National Academy Press.

Mowery, D. 1998. Collaborative R&D: how effective is it. *Issues in Science and Technology* Fall, pp. 37-44.

Mowery, D., and N. Rosenberg. 1998. *Paths of Innovation: Technological Change in 20th Century America*. New York: Cambridge University Press.

Mowery, D., and N. Rosenberg. 1989. *Technology and the Pursuit of Economic Growth*. New York: Cambridge University Press.

Nadiri, I., 1993. *Innovations and Technological Spillovers.* NBER Working Paper No. 4423.

National Advisory Committee on Semiconductors, 1989. *Semiconductors: A Strategic Industry at Risk.* A Report to the President and the Congress, Semiconductor Industry Association, Washington, D.C.

National Advisory Committee on Semiconductors, 1991. *Toward a National Strategy for Semiconductors.* Semiconductor Industry Association, Washington, D.C.

National Research Council, 1996. *Conflict and Cooperation in National Competition for High-Technology Industry*. Washington, D.C.: National Academy Press.

National Research Council, 1998. *Effectiveness of the United States Advanced Battery Consortium as a Government-Industry Partnership*, Washington, D.C.: National Academy Press.

National Research Council, 1999. *Funding A Revolution: Government Support for Computing Research.* Washington D.C.: National Academies Press.

Nelson, R. R. 1982. *Government and Technological Progress*. New York: Pergamon.

Nelson, R. R. 1986. Institutions supporting technical advances in industry. *American Economic Review, Papers and Proceedings* 76(2):188.

Nelson, R.R., ed. 1993. *National Innovation System: A Comparative Study*. New York: Oxford University Press.

Okimoto, D. T., 1986. "The Japanese Challenge in High Technology Industry," in R. Landau and N. Rosenberg, eds., *The Positive Sum Strategy*. National Academy Press, Washington, D.C.

Okimoto, D. T., 1989, *MITI and the Market: Japanese Industrial Policy for High Technology Industry.* Stanford University Press, Stanford, California.

Perret, G., 1989. *A Country Made by War: From the Revolution to Vietnam—The Story of America's Rise to Power*. New York: Random House.

Powell, Jeanne, 1998. *Small-Firm Experience in the Advanced Technology Program*. Unpublished report. June.

Powell, Jeanne, 1997. Development, Commercialization, and Diffusion of Enabling Technologies: Progress Report for Projects Funded 1993-1995. NISTIR 6098, December.

Powell, Jeanne, 1997.*The ATP's Business Reporting System: A Tool for Economic Evaluation.* The Evolution of Firms and Industries. Helsinki, Finland: Tilastokesus Statistikcentralen Statistics Finland.

President's Commission on Industrial Competitiveness, 1985. *Global Competition: The New Reality.* Government Printing Office, Washington, D.C., 2 vols.

Research Triangle Institute, 1998. *Framework for Evaluating the Economic Benefits to the Nation of Medical Technologies Funded by the ATP, with Preliminary Application to Tissue Engineering Projects Funded by ATP from 1990 to 1996*. NIST GCR 97-737.

Romer, P. 1990. Endogenous technological change. *Journal of Political Economy* 98:71–102.

Ruegg, Rosalie T., 1997. *The Advanced Technology Program's Evaluation Plan and Progress.* 7th International Forum on Technology Management. November.

Ruegg, Rosalie T., 1998. "The Advanced Technology Program, Its Evaluation Plan, and Progress in Implementation." *The Journal of Technology Transfer*, vol. 23(2):5-10, Summer.

Ruegg, Rosalie T., 1996. *Guidelines for Economic Evaluation of the Advanced Technology Program.* NISTIR 5896 - November.

Saxenian, A. 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128.* Cambridge, Mass.: Harvard University Press.

Silber, Bonnie, Silber & Associates, 1996. *Survey of Advanced Technology Program 1990-1992 Awardees: Company Opinion About the ATP and its Early Effects*. NIST GCR 97-707.

Spender, J. C., 1997. "Publicly Supported Non-Defense R&D: the USA's Advanced Technology Program." *Science and Public Policy*. February, pp. 45-52.

Stowsky, J., 1996. "Politics and Policy: The Technology Reinvestment Program and the Dilemmas of Dual Use." Mimeo, University of California.

Solomon Associates, 1993. *The Advanced Technology Program, An Assessment of Short-Term Impacts: First Competition Participants*. February.

Wang, A. J., 1998. "Key Concepts in Evaluating Outcomes of ATP Funding of Medical Technologies." *The Journal of Technology Transfer*, 23(2): 61-65, Summer.

Wessner, C., ed., 1997. *International Friction and Cooperation in High-Technology Development and Trade*. Washington, D.C.: National Academy Press.

Wessner, C., ed., 1999. *Industry-Laboratory Partnerships: A Review of the Sandia Science and Technology Park Initiative*. Washington, D.C.: National Academy Press.

Wessner, C., ed., 1999. *New Vistas in Transatlantic Science and Technology Cooperation*. Washington, D.C.: National Academy Press.

Wessner, C., ed., 1999. *The Small Business Innovation Research Program: Challenges and Opportunities*. Washington, D.C.: National Academy Press.

World Bank, 1993. *The East Asian Economic Miracle: Economic Growth and Public Policy,* Oxford University Press, New York.

Yager, L. and Schmidt, R., 1997. *The Advanced Technology Program: A Case Study in Federal Technology Policy*. Washington, D.C.: American Enterprise Institute.

Zachary, G. P., 1997. *Endless Frontier: Vannevar Bush, Engineer of the American Century*. New York: The Free Press.

Annex B:
Participants List

Philip Abelson
AAAS

Arthur J. Alexander
Japan Economic Institute

Maggie Angell
Dewey Ballantine

John Aybar
National Academy of Sciences

Susanne Bachtel
National Research Council

Claude Barfield
American Enterprise Institute

Jon Baron
DoD/SBIR

Micheal Baum
NIST

Barbara Bauman
EPRI

Brian Belanger
NIST

Richard Bissell
National Research Council

Darin Boville
NIST

Barry Bozeman
Georgia Institute of Technology

Kelvin Brockbank
Life Science Holdings, Inc.

Kelly Carnes
Department of Commerce

Connie Chang
NIST

Speakers are italicized.

Iain Cockburn
University of British Columbia

William Colglazier
National Research Council

Mark Crawford
New Technology Week

Michael Darby
University of California at Los Angeles

Michael Daum
Department of Commerce

Brian Delroy
Embassy of Australia

Jennifer Dowling
SEMI

Mitch Eggers
Genometrix, Inc.

Linda Ewing
United Auto Workers

Maryann Feldman
Johns Hopkins University

Robert Finni
Office of Congressman Amo Houghton

Jeffrey Fisher
Solectria Corporation

Kenneth Flamm
University of Texas

Peter Ford
General Electric Company

Anup K. Ghosh
Reliable Software Technologies

David Gibson
X-Ray Optical Systems, Inc.

David Goldston
Office of Representative Sherman Boehlert

Heike Grimm
Union Mittelstaendischer Unternehmen

Carlos Grinspon
NIST

Jeff Grove
House Committee on Science

Matthew Heyman
NIST

Christopher Hill
George Mason University

Laura T. Holliday
National Research Council

John B. Horrigan
National Research Council

Shirley Hurwitz
NIST

Steven Izatt
IBC Advanced Technologies, Inc.

Ray Kammer
NIST

Henry Kelly
White House Office of Science and Technology Policy

Maryellen Kelley
Carnegie Mellon and NIST

David King
NIST

Jean-Francois Large
French Embassy

Alan Lauder
DuPont

William Lehr
Columbia University

Joshua Lerner
Harvard Business School

Al Link
University of North Carolina at Greensboro

William Long
Business Performance Research Associates

Janet Lynch
General Electric

Sheila Martin
Research Triangle Institute

Purabi Mazumdar
NIST

Anne-Marie Mazza
National Research Council

Clark McFadden
Dewey Ballantine

Stephen A. Merrill
National Research Council

Youhyoun Moon
Korean Embassy

William Morin
Sayer and Associates

Julie Moses
British Embassy

Uwe Muller
Vysis, Inc.

Richard Nelson
Columbia University

William Newall
Axys Pharmaceuticals, Inc.

Robert Norwood
NASA Headquarters

Laura Ost
NIST

Mark Pittenger
Osiris Therapeutics, Inc.

Lura Powell
NIST

Richard Ramseyer
Honeywell Technology Center

Samuel Rankin, III
American Mathematical Society

Ralph Resnik
Extrude Hone Corporation

Laura Rheintgen
National Academy of Sciences

Stephen Rock
Stanford University, Aero/Astro

Sally Rood
Federal Laboratory Consortium

Rosalie Ruegg
NIST

Richard Russell
House Committee on Science

Susannah Schiller
NIST

Katherine Schinasi
NIST

Volker Schlegel
German Embassy

Jeffrey Schloss
NIH

Stanley Schneider
Real-Time Innovations, Inc.

Craig Schultz
National Research Council

Brij Seth
Westinghouse Power Generation

Anil Sethi
Sequoia Software Corporation

Manny Sieradzki
Diamond Semiconductor Group, Inc.

Bill Spencer
SEMATECH

J.C. Spender
New York Institute of Technology

Todd Spener
Charter Financial

Marc Stanley
NIST

Richard Spivak
NIST

John Taylor
National Venture Capital Association

James Turner
House Committee on Science

David A. Villarreal
Department of Commerce

Nicholas Vonortas
George Washington University

Caroline Wagner
The RAND Corporation

Andrew Wang
NIST

Todd Watkins
Lehigh University

Charles Wessner
National Research Council

Philip Winkler
Air Products and Chemicals, Inc.

Egon Wolff
Caterpillar, Inc.

Karl Wollin
German Embassy

Loren Yager
General Accounting Office

Jack Yedvish
NASA Headquarters

Joel Yudken
AFL-CIO

Lynne Zucker
University of California at Los Angeles