CHAPTER II
LITERATURE REVIEW

In order to understand this dissertation study evaluating government laboratory technology transfer, it is necessary to have a broad context regarding science and technology policy. Therefore, this chapter is divided into two sections. The first section deals with the context for technology transfer activities and their evaluation, from technology policy to government laboratory policy. It covers how the field of government technology transfer has evolved from the trends of the 1980s and 1990s introduced in Chapter I.

The second section of this chapter deals with the policy, practice, and evaluation of technology transfer. This dissertation is not a program evaluation, it is an assessment of the effectiveness of the technology transfer legislation and policies to date. However, performing a policy assessment of this type draws upon techniques used in program evaluation. The section begins by discussing the evaluation of technology transfer as part of broader science and technology programs, such as efforts to evaluate the impacts of R&D. It proceeds to discussing the evaluation of technology transfer explicitly. Table B summarizes evaluation efforts by or for the government, proceeding from the legislative branch to the executive departments and independent agencies. It also covers inter-agency and multi-agency analyses, some conducted by outside evaluators. A short section at the end of the chapter points out how this study fits into the existing evaluation efforts.

As the chapter progresses, it becomes apparent that most of our knowledge base and the literature in this area is in the form of reports, such as from from policy organizations and committees. Relatively little of the literature is in the form of refereed journals or books. Related literature not noted in the chapter is listed in the bibliography.

SECTION ONE - THE CONTEXT

<u>Science and Technology Policy Trends</u>

The three trends impacting science and technology are discussed in the following order: defense conversion, international competitiveness, and attention to the budget deficit.[1]

End of the Cold War Called for New Missions

The impact of defense conversion on the U.S. science and technology system is evident. The National Academy of Sciences, which provides science-related advice to Congress, produced a series of science and technology policy reports in the 1980s and 1990s including a landmark piece in 1993 which showed how, instead of being driven by the Cold War, science and

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[1]For purposes of this chapter, the trends are discussed separately although they are actually inter-related.

technology now require new national objectives.[2] In addition to military security, these new goals include such as industrial performance, health care, and environmental protection.

The Carnegie Commission on Science, Technology, and Government is another group which examined technology policy from the angle of changing global relations. Twenty reports from the Carnegie Commission during the 1980s and early 1990s[3] culminated in a "concluding report" in 1993. It called for a "transformation" in the way science and technology policy making is organized in all branches of government in order to meet new challenges.[4] The "challenges of the human future" include encouraging long-term economic growth, sustaining the environment, and creating and maintaining peaceful relations among nations in the post-Cold War world.

Leading up to this, Congress had established funding through the Defense Department for consortia working in certain technology areas, such as SEMATECH, so that the government would not be dependent upon potentially unfriendly foreign sources for key technologies such as semiconductors and microchips.[5] In the early 1990s, the Office of Science and Technology Policy (OSTP)[6] and the Departments of Commerce[7] and Defense[8] all analyzed specific technology and industry sectors from a public policy perspective, producing summaries of "critical" or "emerging" technologies considered essential to the nation's well-being whether economic well-being or national security. The Defense Department in conjunction with the

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[2]National Academy of Sciences, Panel on the Government Role in Civilian Technology, *The Government Role in Civilian Technology: Building a New Alliance*, Washington, D.C.: National Academy Press, ISBN 0-309-04630-0, 1992. Also, National Academy of Sciences, Committee on Science, Engineering, and Public Policy, *Science, Technology and the Federal Government: National Goals for a New Era*, Washington, D.C.: National Academy Press, 1993.

[3]One of the last reports in the series was: Carnegie Commission on Science, Technology and Government, *A Science and Technology Agenda for the Nation: Recommendations for the President and Congress*, 1992.

[4]Carnegie Commission on Science, Technology, and Government, *Science, Technology, and Government for a Changing World*, Concluding Report of the Carnegie Commission, ISBN 1-881054-11-X, April 1993.

[5]See, for example, Congressional Budget Office, *Using R&D Consortia for Commercial Innovation: SEMATECH, X-Ray Lithography, and High Resolution Systems*, July 1990.

[6]Office of Science and Technology Policy, *Report of the National Critical Technologies Panel*, March 1991. OSTP has updated its review more recently, as follows: Office of Science and Technology Policy, National Science and Technology Council, National Critical Technologies Review Group, *National Critical Technologies Report (1995)*, March 1996.

[7]Department of Commerce, Technology Administration, *Emerging Technologies: A Survey of Technical and Economic Opportunities*, Spring 1990.

[8]Department of Defense, *Critical Technologies Plan for the Committees on Armed Services, United States Congress*, March 15, 1990. An earlier version was Department of Defense, *The Department of Defense Critical Technologies Plan*, May 1989.

Commerce Department's Export Administration had been doing this for years; the new element was the economic aspect. The technology consortia, which were originally intended for a defense purpose, were urged to take on a commercial purpose.[9] Subsequently, several technology-related trade associations produced comparisons of the key technology lists and began producing "road maps" of industry and technology sectors.[10] Similarly, the private-sector Council on Competitiveness specified critical technologies in 1991 and recommended ways to ensure U.S. competitiveness in those areas.[11] The Congressional Research Service followed suit with a 1993 summary on legislative and executive branch activities regarding critical technology policy-making.[12]

In terms of planning and implementing the defense conversion, the Congressional Office of Technology Assessment addressed strategies for converting the military-industrial complex to civilian uses.[13] The Economic Development Administration at the Commerce Department provided a historical context for defense conversion, outlining how the Cold War defense conversion differed from previous conversions of this century, particularly World War II, the Korean War, and the Viet Nam War.[14]

Some in the science and technology policy circles would say it is a good thing the Cold War conversion unfolded, because science and technology policy was "adrift" at that point, and defense conversion gave this area a new focus.[15] One result of all this was the Technology Reinvestment Project, touted at times as a defense conversion project and at other times as a dual use technology funding program before being cut from the budget.

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[9]John Alic, Lewis Branscomb, Harvey Brooks, Ashton Carter and Gerald Epstein, *Beyond Spinoff: Military and Commercial Technologies in a Changing World*, Cambridge, Massachusetts: Harvard Business School Press, 1992.

[10]See, for example, Aerospace Industries Association of America, Inc., *Key Technologies for the 1990s, An Overview*, Washington, D.C., November 1987, updated version.

[11]Council on Competitiveness, *Gaining New Ground: Technology Priorities for America's Future*, Washington, D.C., 1991.

[12]Congressional Research Service, *Critical Technologies: Legislative and Executive Branch Activities*, 93-734 SPR, 1993.

[13]Office of Technology Assessment, *Redesigning Defense: Planning the Transition to the Future U.S. Defense Industrial Base*, Washington, D.C.: U.S. Government Printing Office, 1991; and, Office of Technology Assessment, *Building Future Security: Strategies for Restructing the Defense Technology and Industrial Base*, Washington, D.C.: U.S. Government Printing Office, 1992.

[14]Department of Commerce, Economic Development Administration, *From War to Peace: A History of Past Conversions*, 1993.

[15]Deborah Shapley and Rustom Roy, *Lost at the Frontier: U.S. Science and Technology Policy Adrift*, Philadelphia, Pennsylvania: Institute for Scientific Information Press, 1985.

The defense conversion of the 1980s occured at a time when there were concerns that technology had the capability to displace masses of workers, an issue addressed by several groups.[16] On this issue, in particular, defense conversion merged with the competitiveness trend, discussed next.

Competitiveness Spawned Interest in Technology Policy

During the 1980s, when it appeared that certain high-technology sectors of Japan's economy had overtaken the United States, a series of organizations sponsored studies comparing the United States, Japan, and other industrialized nations. A National Academy of Sciences project resulted in books of readings,[17] including a report on an economic study which found that the contribution of technological change was the most important source of growth to five industrialized nations.[18] Similarly, the American Enterprise Institute sponsored a multi-year project, "Competing in a Changing World Economy," and a resulting publication offered a five-nation comparison of high-technology policies.[19] Also, the National Science Foundation sponsored a number of studies on the high-tech sectors of individual nations, as well as global comparisons.[20] Even the General Accounting Office examined how the United States compared to Germany and Japan with regard to government policies and corporate activities as they impact competitiveness.[21]

It became evident that technology is a driver of economic growth and a major contributor to international competitiveness. This theme spanned several political administrations at the national level. Beyond the international comparisons, the early domestic literature included a

[16]National Academy of Sciences, Committee on Science, Engineering and Public Policy, Panel on Technology and Employment, *Technology and Employment: Innovation and Growth in the U.S. Economy*, Richard M. Cyert and David C. Mowery, editors, Washington, D.C.: National Academy Press, 1987.

[17]Nathan Rosenberg, Ralph Landau and David C. Mowery, editors, *Technology and the Wealth of Nations*, 1992. See also, Bruce R. Guile and Harvey Brooks, editors, *Technology and Global Industry: Companies and Nations in the World Economy*, National Academy of Engineering Series on Technology and Social Priorities, Washington, D.C.: National Academy Press, 1987.

[18]Michael J. Boskin and Lawrence J. Lau, "Capital, Technology, and Economic Growth," *Technology and the Wealth of Nations*, Nathan Rosenberg, Ralph Landau and David C. Mowery, editors, Washington, D.C.: National Academy Press, 1992.

[19]Richard R. Nelson, *High-Technology Policies: A Five-Nation Comparison*, New York: Columbia University, 1988.

[20]See, for example, Francis W. Rushing and Carole Ganz Brown, editors, *National Policies for Developing High Technology Industries: International Comparisons*, Westview Special Studies in Science, Technology, and Public Policy, Boulder, Colorado: Westview Press, 1986.

[21]General Accounting Office, *Competitiveness Issues: The Business Environment in the United States, Japan, and Germany*, Report to Congressional Requesters, GAO/GGD-93-124, August 1993.

1987 report by the Conference Board and the National Governors Association on the role of science and technology in economic competitiveness.[22]

In the mid-1980s, the National Academy of Sciences initiated an ongoing dialogue between engineers and economists in a project focused on harnessing technology for economic growth.[23] This dialogue was continued in a 1991 report, *Technology and Economics*,[24] from the Academy's sister organization, the National Academy of Engineering. Since first being written in the 1980s, Congressional Research Service (CRS) reports on this topic have been periodically updated, as well.[25]

Towards the end of the Bush Administration in the late 1980s, the White House Office of Science and Technology Policy (OSTP) developed the short document, *U.S. Technology Policy*.[26] Looking back, it appears somewhat one-dimensional, yet it was the first official government technology policy.[27] President Bush also created an interagency Council on Competitiveness, another first, which was chaired by the vice president.[28]

As the relationship between technology and the economy became more universally-accepted, the subsequent presidential administration made this link more explicit. The Clinton Administration presented its technology policy in 1993[29] and, within the year, produced a brief

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[22]National Governors Association and the Conference Board, *The Role of Science and Technology in Economic Competitiveness*, Final Report Prepared for the National Science Foundation, September 1987.

[23]National Academy of Sciences, *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, Washington, D.C.: National Academy Press, 1986.

[24]National Academy of Engineering, *Technology and Economics*, Washington, D.C.: National Academy Press, ISBN 0-309-04397-2, 1991.

[25]See, for example, Wendy H. Schact and Glenn J. McLoughlin, *Technology and Trade: Indicators of U.S. Industrial Innovation*, Congressional Research Service Review, October 1986. See also, Glenn McLaughlin and Richard E. Rowberg, "Linkages Between Federal Research and Development Funding and Economic Growth," Congressional Research Service series, *Economic Policymaking in Congress: Trends and Prospects*, February 21, 1992.

[26]Executive Office of the President, Office of Science and Technology Policy, *U.S. Technology Policy*, September 26, 1990.

[27]Technology policy first appeared during the Carter Administration, then disappeared during the subsequent Reagan Administration.

[28]This group should not be confused with the Competitiveness Policy Council, an independent advisory committee, or the private-sector Council on Competitiveness, both of which appear elsewhere in this chapter.

[29]President William J. Clinton and Vice President Albert Gore, Jr., *Technology for America's Economic Growth, A New Direction to Build Economic Strength*, February 22, 1993.

status report on implementing it.[30] A Commerce Department report noted that the Clinton Administration marked the first time the various bureaus and agencies of that department had developed an integrated comprehensive strategy for technology policy.[31] Because technology programs have been a cornerstone of the Clinton Administration, the White House put into place a structure to produce a number of policy and position papers early in the Administration. President Clinton created the National Science and Technology Council (NSTC) within OSTP in 1993 which subsumed the activities of several previous groups within OSTP's purvue.[32] The NSTC is a virtual agency for coordinating R&D across agencies, chaired by the Under Secretary of Commerce for Technology. In 1994, the Clinton Administration released the first major statement on science policy since the Carter Administration which called for the government to move beyond its Cold War focus on military-driven research.[33] Perhaps more importantly, this was also the first time the government linked basic research with competitiveness. About the time the Commerce Department was criticized[34] for producing "public relations" reports for the Administration,[35] it also produced some analytical reports. For example, the Commerce Department's Economics and Statistics Administration (ESA) showed that the use of advanced technologies was associated with enhanced plant survival and faster employment growth.[36] More specifically, ESA found that companies investing in technologies paid 14.4 percent higher wages than other companies. The National Institute of Standards and Technology's (NIST) 1995 report to Congress, prepared by the NIST Senior Economist, provided economic analyses

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[30] White House, *Technology for Economic Growth: President's Progress Report*, November 1993.

[31] Department of Commerce, *Commerce ACTS: Advanced Civilian Technology Strategy*, Draft for Public Comment, November 1993.

[32] The Carnegie Commission and others had been calling for structural changes in the Executive Office for handling science and technology policy issues. See, for example, Carnegie Commission on Science, Technology and Government, *Technology and Economic Performance: Organizing the Executive Branch for a Stronger National Technology Base*, September 1991.

[33] Office of Science and Technology Policy, National Science and Technology Council, Committee on Fundamental Science, *Science in the National Interest*, August 1994. The overall goal for the nation is to maintain leadership across the frontiers of scientific knowledge; sub-goals relate to connections between research and national goals, etc. This was the first in a two-part series; its companion piece was *Technology in the National Interest*, noted below.

[34] See, for example, Neil MacDonald, "Tech Policy Veteran Puzzles Over Recent Federal Episodes," *McGraw-Hill Companies' Federal Technology Report* (November 20): 9-10, 1997.

[35] The Commerce Department's Technology Administration assisted OSTP in producing reports such as: Office of Science and Technology Policy, National Science and Technology Council, Committee on Civilian Industrial Technology, *Technology in the National Interest*, July 1996. This was followed by the OSTP biennial report to Congress: Executive Office of the President, Office of Science and Technology Policy, National Science and Technology Council, *Science and Technology Shaping the Twenty-First Century*, 1997.

[36] Department of Commerce, Economics and Statistics Administration, Office of the Chief Economist, *Technology, Economic Growth and Employment*, 1994.

justifying government investments in technological infrastructure.[37]

During the years leading up to passage of the 1986 and 1989 technology transfer acts, Congress held a series of hearings on science and technology issues. A House Technology Policy Task Force produced the report, *Technology Policy and its Effect on the National Economy*, based upon testimony presented by expert witnesses.[38] This was during the time when the relationship between technology and competitiveness was just beginning to be understood. Eventually, the themes in the literature progressed to recommendations on how the relationship between technology and the economy should be influenced (such as through further defense conversion, workforce training and education, technology funding programs, technical assistance and manufacturing extension programs, industry consortia, or technology transfer).

The Competitiveness Policy Council (CPC) is an independent federal advisory committee created in the late 1980s,[39] encompassing a number of "subcouncils" including one for technology policy. The subcouncil on technology, headed by the former director of the National Science Foundation, produced a series of technology policy reports to accompany CPC's annual reports to the President and Congress. The most recent technology policy report,[40] accompanying CPC's 1994 report,[41] addressed a number of issue areas impacting competitiveness broadly including: financial markets and capital formation, trade policy, manufacturing issues, and transportation, telecommunications and other public infrastructure. The technology policy report specifically documented new concerns in the technology area, such as the need for a larger federal role in technology financing, and the need to broaden existing preferences for U.S. firms.[42]

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[37]National Institute of Standards and Technology, *Technology and Economic Growth: Implications for Federal Policy*, Prepared by Gregory Tassey, Senior Economist, October 1995.

[38]House of Representatives, Committee on Science, Space and Technology, *Technology Policy and its Effect on the National Economy: Report Prepared by the Technology Policy Task Force,* Washington, D.C.: U.S. Government Printing Office, 1988.

[39]This council was created by Congress in the 1988 Omnibus Trade and Competitiveness Act. The President and Congress appoint twelve council members.

[40]Competitiveness Policy Council, *Pursuing a New Technology Policy,* Report of the Critical Technologies Subcouncil, Erich Bloch, Chairman, May 1994.

[41]Competitiveness Policy Council, *Saving More and Investing Better: A Strategy for Securing Prosperity*, Fourth Report to the President and Congress, September 1995. Previous CPC reports to the President and Congress included: *Promoting Long-Term Prosperity* (Third Report, May 1994; *A Competitiveness Strategy for America* (Second Report, March 1993); and, *Building a Competitive America* (First Report, 1992). An October 1993 "progress report," *Enhancing American Competitiveness,* discussed problem areas.

[42]Previous CPC technology policy reports included: Competitiveness Policy Council, *Implementing Technology Policy for a Competitive America*, Report of the Critical Technologies Subcouncil, August 1993; and, Competitiveness Policy Council, *Technology Policy for a Competitive America,* Report of the Critical Technologies Subcouncil, March 1993.

The Center for Strategic and International Studies (CSIS) is an example of an independent public policy research institution focusing on science and technology policy, among other issue areas. In 1996, CSIS contributed a major report on international competitiveness which noted that future U.S. competitiveness hinged on the ability to integrate the elements of innovation into a national strategy, including: corporate competitiveness, a world-class science and technology system, a strong education system, and an investment-friendly environment.[43]

The private-sector Council on Competitiveness has summarized the technology policy themes every few years.[44] To do so, the Council generally surveys its hundred or more members who are CEOs, and compares U.S. data on investments, productivity, trade, savings and standard of living to data of other industrialized nations. The Council's 1993 policy assessment[45] examined eleven recommendations covering the following topics: federal R&D, coordination and cooperation, tax policy, and U.S. manufacturing.[46] It noted that a consensus on the issues had been evolving since the mid-1980s, and determined that, in areas such as refocusing the national laboratories from defense to industry needs, "moderate progress" was made.

Just as the defense conversion trend brought about the Technology Reinvestment Project, a result of the international competitiveness trend was increased funding for the Manufacturing Technology Centers program. This federal-state initiative was later re-named the Manufacturing Extension Partnership.

Big Science Era Ended, Attention Turned to the Budget Deficit

Vannevar Bush's landmark 1945 book, *Science: The Endless Frontier*, marked the beginning of the "big science" era.[47] After fifty years, several works marked the end of big science, such as the Council on Competitiveness 1996 report, *Endless Frontier, Limited Resources: U.S. R&D Policy for Competitiveness*.[48] Given that expectations were increasing and

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[43]Center for Strategic and International Studies, *Global Innovation/ National Competitiveness*, Washington, D.C., 1996.

[44]The more recent 1996 version of the Council's policy assessment was largely a compilation of essays by well-known commentators: Council on Competitiveness, *Competitiveness Index 1996: A Ten-Year Strategic Assessment*, Washington, D.C., ISBN 1-889866-18-0, 1996.

[45]Council on Competitiveness, *Technology Policy Implementation Assessment 1993*, Washington, D.C., 1993.

[46]These focus areas grew out of the Council's 1991 assessment: Council on Competitiveness, *Gaining New Ground: Technology Priorities for America's Future*, Washington, D.C., 1991.

[47]Vannevar Bush, *Science: The Endless Frontier*, first edition, 1945; 1990 edition published on the occasion of the Fortieth Anniversary of the establishment of the National Science Foundation which the publication helped to create.

[48]Council on Competitiveness, *Endless Frontier, Limited Resources: U.S. R&D Policy for Competitiveness*,

resources were decreasing, the report's message was that priorities and mechanisms must be established so that industry, academia and government can share.[49] It also called for an end to the politicized debate over the federal role in R&D, and provided guidelines for industry, government and academia to make the paradigm shift necessary in the post-Cold War era.

As budget issues came to the forefront in the 1990s, several reports were of significance. The National Academy of Sciences issued a 1995 report, known as the "Press Report" after its chair (former presidential science advisor) Frank Press, which recommended new criteria for judging and funding R&D programs.[50] Because the science community has traditionally been conservative in dealing with federal budget matters (probably due to its favorable treatment over the decades), this community did not greet this report favorably.[51]

A 1996 Congressional Research Service[52] report is another example of the attention among policy circles to the science and technology funding issue.[53] This report on budget constraints suggested creating a Department of Science and Technology to better coordinate federal R&D funding priorities, given funding reductions by the federal and state governments and industry.

Washington, D.C., April 1996.

[49]The report's appendices are in-depth assessments of R&D in six industry sectors that are central to U.S. competitiveness: aircraft, automotive, chemical, electronics, information technologies, and pharmaceuticals.

[50]National Academy of Sciences, Committee on Criteria for Federal Support of Research and Development, *Allocating Federal Funds for Science and Technology*, Frank Press, Committee Chair, Washington, D.C.: National Academy Press, 1995.

[51]Frank Press, "Needed: Coherent Budgeting for Science and Technology," *Science* 270 (December 1): 1448-1450, 1995.

[52]The Congressional Research Service compiles regular reports on federal R&D funding and R&D funding for specific departments and agencies. See for example: Congressional Research Service, *Research and Development Funding: Fiscal Year 1998*, CRS Issue Brief prepared by Michael E. Davey, Science Policy Research Division, IB97023, Updated December 17, 1997; Congressional Research Service, *The Department of Energy FY1998 Research and Development Budget and Issues,* CRS Report for Congress prepared by Richard E. Rowberg, Science Policy Research Division, 97-233 SPR, Updated December 3, 1997; Congressional Research Service, *The National Aeronautics and Space Administration: An Overview With FY1997 and FY1998 Budget Summaries*, CRS Report for Congress prepared by David P. Radzanowski, Science Policy Research Division, 97-634 SPR, June 10, 1997; Congressional Research Service, *Federal R&D Funding Trends in Five Agencies: NSF, NASA, NIST, DOE (Civilian) and NOAA*, CRS Report for Congress prepared by Michael E. Davey, Science Policy Research Division, 97-126 SPR, January 17, 1997.

[53]Congressional Research Service, *Research and Development Funding in a Constrained Budget Environment: Alternative Support Sources and Streamlined Funding Mechanisms*, 1996. See also, Congressional Research Service, *Research and Development: Priority Setting and Consolidation in Science Budgeting*, CRS Issue Brief prepared by Genevieve J. Knezo, Science Policy Research Division, IB94009, Updated January 15, 1998.

As defense conversion, the international economic wars, and the budget debate all geared up, these three trends converged in the mid-1990s. Conservative Republicans accused the government of "picking winners" with its funding of technology programs.[54] This resulted in partisan wars over science and technology, and a new round of policy analyses in the mid-1990s focused on the role of government in science and technology. In response to the more conservative views of the new Congress, some of the reports offered alternative approaches to heavy government involvement such as a 1995 Congressional Research Service report which outlined potential indirect inducements to fostering commercial technology development in lieu of direct government spending.[55] Other reports were supportive of the Administration's more liberal spending approach, such as a 1995 Council of Economic Advisors report which advocated more R&D funding.[56] On this issue, the Competitiveness Policy Council managed to appear bipartisan with a white paper by the former Commerce Department Under Secretary for Technology which provided a historical view of the government's role in technology policy.[57]

Trends Affected Government Laboratory Policy

The several trends outlined above caused particular attention to be focused on the laboratories producing and stockpiling nuclear weapons, the Department of Energy's (DOE) defense laboratories. The issue of the relevancy of these laboratories came to a head during highly-politicized discussions about downsizing the DOE bureaucracy or disbanding it altogether.

In 1992, an advisory board to the Secretary of Energy submitted a report which emphasized the changing environment and new national challenges, and presented "guiding principles" for defining each laboratory's role.[58] An advisory board to the next Energy Secretary

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[54]Generally, it is contrary to the role of government to identify and support winners. Illustrative editorials and commentaries on both sides of this topic include: "When the State Picks Winners," Editorial in *The Economist* (January 9): 13-14, 1993; Robert W. Rycroft and Don E. Cash, "Technology Policy Requires Picking Winners," Commentary in *Economic Development Quarterly* 6(3/August): 227-240, 1992.

[55]Congressional Research Service, Science Policy Research Division, *The Federal Role in Technology Development*, CRS Report for Congress prepared by Wendy H. Schacht, 95-50 SPR, 1995, October 15, 1996 and updated January 12, 1998. See also Congressional Research Service, *Industrial Competitiveness and Technological Advancement: Debate Over Government Policy*, CRS Issue Brief prepared by Wendy H. Schacht, Science Policy Research Division, IB91132, Updated December 5, 1997; and, Congressional Research Service, *R&D Partnerships: Government-Industry Collaboration*, CRS Report for Congress prepared by Wendy H. Schacht, 95-499 SPR, Updated January 12, 1998.

[56]White House, Council of Economic Advisors, *Supporting Research and Development to Promote Economic Growth: The Federal Government's Role*, October 1995.

[57]Robert M. White, *U.S. Technology Policy: The Federal Government's Role*, Paper Commissioned by the Competitiveness Policy Council, September 1995.

[58]Department of Energy, Secretary of Energy Advisory Board (SEAB), *Report to the Secretary on the DOE National Laboratories*, Prepared by the SEAB Task Force on the DOE National Laboratories, July 1992.

submitted another review of the DOE laboratories and their missions in 1995.[59] This report, known as the "Galvin Report" because the advisory board was headed by former Motorola chair Robert Galvin, received a great deal of fanfare with its release. However, the report's controversial recommendation to re-establish the laboratories as non-profit public corporations was not heeded by DOE top management. The Galvin Report even specified laboratory "metrics" for general laboratory work[60] and for technology transfer activities[61] stating, "The degree to which a laboratory engages in the process of renewal would be a significant measurement." The main theme was change in the laboratories, their missions, and their science.

Meanwhile, Congressional analysts also studied the DOE laboratories. The now-defunct[62] Congressional Office of Technology Assessment produced a duo of reports on defense conversion,[63] with the second report focusing on DOE's three major nuclear weapons laboratories and the issue of redirecting their R&D to civilian missions. Similarly, the Congressional Research Service produced a 1993 report with the same theme, and has revisited the topic since then.[64]

From 1994 to 1996, the General Accounting Office produced a series of reports on the DOE system, beginning with testimony about what a challenge it would be to convert the laboratory missions.[65] GAO developed a baseline inventory of human and capital resources within the national laboratories, and determined their activities were not related to commercial

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[59]Department of Energy, *Alternative Futures for the Department of Energy National Laboratories*, Secretary of Energy Advisory Board Office, Task Force on Alternative Futures, February 1, 1995.

[60]Such as adherence to budgets, adherence to project schedules, and research dead ends now avoidable.

[61]For example: patents filed, inventions disclosed, estimates of cost savings from a given potential application or actual application of technology, lists of technical problems solved, quantity and quality of research papers published, laboratory/ university and laboratory/ industry interactions as well as other collaborative work anecdotes, including CRADA results. The report discouraged the use of two metrics, number of CRADA-related jobs (too "speculative"), and number of CRADAs (fails to measure output or different classes of CRADAs).

[62]OTA was disbanded in 1995 under the auspices of the Republicans' "Contract with America."

[63]Office of Technology Assessment, *Defense Conversion: Redirecting R&D*, Washington, D.C.: U.S. Government Printing Office, 1993. The first report, focused on companies, was: Office of Technology Assessment, *After the Cold War: Living With Lower Defense Spending*, Washington, D.C.: U.S. Government Printing Office, OTA-ITE-524, February 1992.

[64]Congressional Research Service, *DOE Laboratories: Capabilities and Missions*, 93-752 SPR, 1993; more recently, see Congressional Research Service, *Restructuring DOE and Its Laboratories: Issues in the 105th Congress*, CRS Issue Brief prepared by William C. Boesman, Science, Technology, and Medicine Division, IB97012, Updated January 9, 1998.

[65]General Accounting Office, *DOE's National Laboratories: Adopting New Missions and Managing Effectively Pose Significant Challenges*, Testimony before the Subcommittee on Energy and Power, Committee on Energy and Commerce, House of Representatives, GAO/T-RCED-94-113, February 3, 1994.

product development.[66] GAO called for clearer missions and better management[67] and urged a restructuring of the system, but did not make more specific recommendations because it assumed that Congress would come up with various approaches.[68] In 1996, GAO raised a ruckus with a report calling for DOE to recover from private sector partners its investment in technology development and commercialization.[69] DOE officials knew from their experience trying to come up with technology project metrics that the record-keeping requirements would be onerous.

SECTION TWO - EVALUATING TECHNOLOGY TRANSFER

Introduction - Brief History, Current Issues

In the 1970s, 1980s and 1990s, researchers produced countless reports and articles on all aspects of technology transfer, much of it supported by the National Science Foundation and NASA.[70] Early-on, the study of technology transfer was most closely related to the theory and process of technological innovation and diffusion. Everett Rogers, a professor of communications, is considered a classic theorist in this area since he wrote the seminal text, *Diffusion of Innovations*, first published in 1962.[71] The early network of innovation theorists included social scientists from a variety of academic disciplines focusing on how R&D produces new knowledge, resulting in new products, and how such technological innovations impact users and adopting organizations. This aspect of technological innovation overlaps the study of behavioral science and organizational behavior.[72] Modeling the innovation process is also

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[66] General Accounting Office, *National Laboratories: Are Their R&D Activities Related to Commercial Product Development?* Report to Congressional Requesters, GAO/PEMD-95-2, November 1994.

[67] General Accounting Office, *Department of Energy: National Laboratories Need Clearer Missions and Better Management*, Report to the Secretary of Energy, GAO/RCED-95-10, January 1995.

[68] General Accounting Office, *Department of Energy: A Framework for Restructuring DOE and Its Missions*, Report to the Congress, GAO/RCED-95-197, August 1995.

[69] General Accounting Office, *Energy Research: Opportunities Exist to Recover Federal Investment in Technology Development Projects*, Report to the Chairman, Subcommittee on Energy and Environment, Committee on Science, House of Representatives, GAO/RCED-96-141, June 1996.

[70] As examples of studies in this area, which date back several decades, see: Battelle, *Interactions of Science and Technology in the Innovation Process: Some Case Studies*, Final Report, Prepared for the National Science Foundation, Columbus, Ohio: Battelle Columbus Laboratories, Contract NSF-C 667, March 19, 1973; Robert K. Yin et al, *A Review of Case Studies of Technological Innovations in State and Local Services*, Santa Monica, California: RAND Corporation, R-1870-NSF, February 1976; Federal Laboratory Consortium for Technology Transfer, Federal Laboratory-Industry Interaction Working Group, *Interagency Study of ORTA Organization and Operation and Lessons Learned Case Studies in Technology Transfer*, DOE/METC - 85/6019, May 1985.

[71] Everett M. Rogers, *Diffusion of Innovations,* New York: Free Press, ISBN 0-02874074-2, First edition, 1962, Third edition, 1983, Fourth edition, 1995; see also, Everett M. Rogers, with the assistance of F. F. Shoemaker, *Communication of Innovations: A Cross-Cultural Approach*, New York: Free Press, 1971.

[72] There is a wide variety of published material on the behavioral sciences and the examples are

related to another field, the management of R&D and product development cycles within organizations.[73] The early innovation theorists informally networked around a National Science Foundation (NSF) program on the innovation process. Several researchers in this network originated from the University of Michigan's Center for Research on the Utilization of Scientific Knowledge. This team, including Louis Tornatzky and J. D. Eveland, compiled a comprehensive literature review of the field of technological innovation.[74] Later, the team summarized more than a decade of research into an updated book, the lead authors being Tornatzky and Mitchell Fleischer.[75]

Early-on, the theory and practice of technology transfer related to the dissemination and communication of scientific and technical information.[76] This perspective viewed technology as a "baton" to be passed off. However, over time, research showed that technology transfer is more effectively accomplished in an integrative fashion involving joint development between a laboratory and outside user. Therefore, more recently, the practice of technology transfer relates to cooperative research, with commercialization generally being the intended outcome of such joint development.[77] Most recently, the practice of technology transfer also involves the complicated intellectual property and other legal aspects of partnerships.[78] A variety of how-to

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innumerable.

[73]See, for example, the *Journal of Product Innovation Management*, bimonthly publication of the Product Development and Management Association (PDMA), Elsevier Science, Inc., publisher, ISSN 0737-6782. See also, Milton D. Rosenau, Jr., editor, *The PDMA Handbook of New Product Development*, John Wiley & Sons, Inc.

[74]Louis G. Tornatzky, J. D. Eveland et al, *The Process of Technological Innovation: Reviewing the Literature*, National Science Foundation, Division of Industrial Science and Technological Innovation, Productivity Improvement Research Section, May 1983.

[75]Louis G. Tornatzky, Mitchell Fleischer et al, *The Processes of Technological Innovation,* Lexington, Massachusetts: Lexington Books, ISBN 0-669-20348-3, 1990.

[76]The information-related "technology transfer" literature covers the gamut from archiving to database systems for disseminating information, related to the field of library and information science. For example, laboratory scientists write scientific and technical papers, but they are not responsible for publishing journals or maintaining databases. Researchers at Syracuse University's School of Information Studies recently studied how information on federal technology is transferred, surveying the distribution media and information-seeking behaviors. The findings are reported in: Rolf T. Wigand, Slawomir J. Marcinkowski and Igor Plonisch, "Transferring Technology on the Information Highway," *Technology Commercialization and Economic Growth, Technology Transfer Society Proceedings, 20th Annual Meeting, July 16-19, 1995, Washington, D.C.*: 267-276, 1995.

[77]See, for example, C. Bruce Tarter, "National Laboratory Partnerships: What Works and What Doesn't," *AAAS Science and Technology Policy Yearbook 1998*, Albert H. Teich et al, editors, American Association for the Advancement of Science, ISBN 0-87168-611-2, p. 265-278, 1997; Wil Lepkowski, "R&D Policy: Cooperation is the Current Byword," *AAAS Science and Technology Policy Yearbook 1998*, Albert H. Teich et al, editors, American Association for the Advancement of Science, ISBN 0-87168-611-2, p. 223-236, 1997.

[78]Alan S. Gutterman and Jacob N. Erlich, *Technology Development and Transfer: The Transactional and Legal Environment*, Westport, Connecticut: Quorum Books, ISBN 1-56720-021-4, 1997.

handbooks in this area are targeted to both industry and laboratory technology transfer officers.[79]

Viewing the process of technology transfer from another angle, it also relates to studies of economic development and regional clustering.[80] This focus often involves technologies transferred from universities and the related entrepreneurial development in technology corridors such as Silicon Valley near Stanford University and Massachusetts' Route 128 near the Massachusetts Institute of Technology.[81] Studies of entrepreneurial behavior, in turn, are related to small business development and the contributions of small firms to the economy.[82] Viewing technology transfer from this angle, government laboratories are relatively new actors in the process.

The entrance of government laboratories into a scenario first dominated (commercially) by universities has brought more interest in program evaluation. And this interest has shifted from performance monitoring and process evaluation to impact evaluation. In any case, Congress passed the Government Performance and Results Act (GPRA) in 1993 which called for general programmatic accountability on the part of federal agencies. It required agencies to set quantitative performance targets and to report annually on their progress. Nevertheless, it was really the partisan budget wars' focus on science and technology that caused both Congress and the Administration to become increasingly concerned with evaluating the effectiveness of federal investments in science and technology, including technology transfer. A number of reports by Congressional committees and Administration entities either called for such measurement activity or actually attempted to assess the outcomes of scientific research and technology.

At the same time that there has been this increased need to justify the direct investment of taxpayer dollars, technology transfer policy has been changing. Philosophically, technology transfer policy has progressed towards a balancing of public and private concerns in order to

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[79]Fred E. Grisson, Jr. and Richard L. Chapman, *Mining the Nation's Brain Trust: How to Put Federally-Funded Research to Work for You*, Reading, Massachusetts: Addison-Wesley Publishing Company, Inc., ISBN 0-201-55015-6, 1992. See also Albert N. Link and Gregory Tassey, editors, *Cooperative Research and Development: The Industry-University-Government Relationship*, Norwell, Massachusetts: Kluwer Academic Publishers, 1989. Also, the FLC and National Technology Transfer Center have produced technology transfer handbooks to accompany their training courses in this area.

[80]See, for example, Sally Rood and Diane Palmintera, *Tapping Federal Laboratories and Universities to Improve Local Economies: The Role of the Mayor and City Government*, Washington, D.C.: U.S. Conference of Mayors, October 1988.

[81]Annalee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Cambridge, Massachusetts: Harvard University Press, 1994; see also, Alistair Brett, David V. Gibson and Raymond W. Smilor, editors, *University Spinoff Companies: Economic Development, Faculty Entrepreneurs, and Technology Transfer*, Lanham, Maryland: Rowman & Littlefield Publishers, Inc., 1991.

[82]See David Birch, *Job Creation in America: How Our Smallest Companies Put the Most People to Work*, New York: Free Press, 1987. On a related note, corporations are involved in technology transfer from the perspective of licensing in technologies or technology transfer within a corporation or a consortia of companies.

provide motivation to commercialize (ie., intellectual property rights for private-sector partners and royalties for government personnel). As noted, the early years of the big science era involved proactive dissemination of government science and technology to the public. Technology transfer provisions somewhat restrict broad dissemination, but the assumption is that American society and societies worldwide will ultimately benefit from resulting contributions to the economy.

Consequently, the studies analyzing government laboratory missions eventually focussed on the laboratories' role in technology transfer, and laboratory policy converged with technology transfer policy. While technology transfer policy has been in state of flux, many groups have offered their policy recommendations in this area. The Commerce Department's Technology Administration summarized technology policy recommendations made by forty industry associations and private organizations contained in nearly a hundred published reports.[83] In the area of technology transfer, the analysis found the two points having the greatest agreement related to: (1) orienting federal laboratories to industry needs, and (2) ensuring private sector input. Several examples are highlighted here.

An advisory committee[84] comprised of individuals from industry, academia, and federal laboratories oversaw a Council on Competitiveness study[85] which made general recommendations on laboratory funding, management, and industry initiatives. The study offered two recommendations regarding technology transfer: (1) authority to sign cooperative R&D agreements should rest with the laboratories, themselves, not their federal agencies, and (2) technology transfer does not require new funds, but a reprioritization of existing funds.

Another steering committee of representatives from industry, academia, national laboratories, and "key government observers" guided a study by CSIS.[86] This project initially focused on technology transfer from DOE's national laboratories. However, the committee found that this ignored the laboratories' multiprogrammatic character and capabilities extending beyond weapons research. It also assumed there were no more challenges for the laboratories, or

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[83]Department of Commerce, Technology Administration, Office of Technology Policy, *Listening to Industry: Business Views on Technology Policy*, Draft for Public Comment, June 1994. CRS summarized ten science policy studies, but this summary was not as specific about technology transfer. See Congressional Research Service, *Analysis of 10 Selected Science and Technology Policy Studies*, CRS Report to Congress, prepared by William C. Boesman, Science Policy Research Division, 97836 SPR, Updated October 24, 1997.

[84]The Council's advisory committee was headed by its Distinguished Fellow, Erich Bloch, who also spearheaded subcommittee studies for the CPC.

[85]Daniel F. Burton, *Industry as a Customer of the Federal Laboratories*, Washington, D.C.: Council on Competitiveness, 1992.

[86]Bruce A. McKenney, *National Benefits from National Labs: Meeting Tomorrow's National Technology Needs*, Final Report of the CSIS National Benefits from National Laboratories Project, Washington, D.C.: Center for Strategic and International Studies, ISBN 0-89206-224-X, 1993.

that industry could address the challenges more effectively. The report outlined three requirements for enhancing benefits from the laboratories ("benefits that go well beyond technology transfer"): (1) identify national missions to meet the nation's grand challenges; (2) create strategic partnerships with industry and academia; and (3) ensure that the agencies of government coordinate an R&D investment strategy. Regarding technology transfer specifically, the report also contained proposals for streamlining the administrative process for cooperative R&D agreements.

Even another group, the Atlantic Council, urged stronger laboratory-industry relationships (through liaison programs, industry briefings, industry assistance in priority-setting, and advisory committees).[87]

It now appears confirmed that the remaining large issues in federal technology transfer policy center around the public-private interface. For example, how do CRADAs fit into the trend to eliminate "corporate welfare"?[88] What is the private sectors' responsibility to provide feedback on technology transfer results? As a Congressional Research Service report succinctly stated, "At issue is whether additional legislative initiatives are necessary to encourage increased technology transfer or if the responsibility now rests with the private sector to use the available resources."[89]

Furthermore, it should be clear by now that evaluating technology transfer differs from evaluating R&D in that there are identifiable activities labelled "technology transfer" beyond the specific research activities, themselves. Nevertheless, some approaches to evaluating technology transfer have grown out of approaches to evaluating R&D. The next section begins by describing R&D evaluation that may (or may not) include explicit technology transfer activities. Table B provides a summary sketch of evaluations described in the upcoming sections.

Evaluating Technology Transfer as Part of Broader R&D Programs

When government laboratory R&D produces economic impacts, this implies the technology is transferred to an outside user. Yet the transfer of the technology may be implicit to the R&D effort. In the mid-1980s, the Office of Technology Assessment investigated whether

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[87] Atlantic Council, *Transfer of Technology to Industry from U.S. Department of Energy Defense Programs Laboratories*, 1992.

[88] Congressional Research Service, *Cooperative R&D: Federal Efforts to Promote Industrial Competitiveness*, CRS Issue Brief prepared by Wendy H. Schacht, Science Policy Research Division, IB89056, Updated December 5, 1997. See also, Congressional Research Service, *Cooperative Research and Development Agreements (CRADAs)*, CRS Report for Congress prepared by Wendy H. Schacht, Science, Technology, and Medicine Division, 95-150 SPR, Updated January 12, 1998.

[89] Congressional Research Service, *Technology Transfer: Use of Federally Funded Research and Development*, CRS Issue Brief prepared by Wendy H. Schacht, Science Policy Research Division, IB85031, Updated December 5, 1997.

the benefits of investments in science programs could be predicted and measured.[90] In its 1986 background report, OTA concluded, "While there are some quantitative techniques that may be of use to Congress in evaluating specific areas of research, basic science is not amenable to the type of economic analysis that might be used for applied research or product development."[91] OTA also said, "even in the business community, decisions about research are much more the result of open communication followed by judgment than the result of quantification."[92]

In 1993, Congress appropriated money for the Office of Science and Technology Policy to explore performance measures for basic research. The project produced a set of nine principles for assessing fundamental science, such as the use of multiple sources of measures, and a mix of quantitative and qualitative indicators and narrative text.[93] It also touted three assessment methods: (1) qualitatively-based peer reviews - either retrospectively, prospectively, or in-process reviews; (2) customer satisfaction ratings - with users of the research products; and (3) quantitative metrics, where possible.

Evaluation by peer review is one area where the field of technology transfer has learned from evaluation of basic science. DOE laboratory researchers were among those pioneering the concept of evaluating technology transfer by peer review. This concept was discussed in a 1994 paper by a research team associated with DOE's High-Temperature Superconductivity program.[94] The procedures and evaluation criteria are those used in peer review for conventional R&D projects, but they were adapted to the characteristics of technology transfer projects.

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[90]OTA undertook this study at the request of the House of Representatives Science Policy Task Force, so its report also appeared as committee print.

[91]Office of Technology Assessment, *Research Funding as an Investment: Can We Measure the Returns? A Technical Memorandum,* OTA-TM-SET-36, Washington, D.C.: U.S. Congress, April 1986.

[92]Ibid.

[93]Office of Science and Technology Policy, National Science and Technology Council, Committee on Fundamental Science, Subcommittee on Research, *Assessing Fundamental Science*, July 1996.

[94]Thomas P. Sheahen et al, "Evaluation of Technology Transfer by Peer Review," *Journal of Technology Transfer* 19 (3/4 December): 100-109, 1994.

TABLE B
R&D AND TECHNOLOGY TRANSFER EVALUATIONS

PROGRAM, SCOPE	SPONSOR/EVALUATOR	APPROACH	RESULT
Basic research	OTA	Analysis	Inconclusive
Fundamental science	OSTP	Analysis	Guidelines
Superconductivity-related Tech Transfer projects	DOE In-house	Peer Review	
R&D by sectors, firms	NSF/ Mansfield & various other economists	Cost-Benefit Cases, IRR	Positive
R&D	NSF/ CHI Research	Bibliometrics	Positive
NASA TU Program	NASA TU/ (1) Mathematica, (2) DRI	Cost-Benefit Cases	Positive
NASA Space Program, R&D	NASA/ (1) Chase Econometrics, (2) MRI	Cost-Benefit	Positive
NASA *Spinoff*	NASA TU/ Chapman	Survey	Positive
NASA Tech Transfer	NASA LaRC/ Bush	Benchmark w/ universities, Surveys, Three Cases	Mixed
NASA LaRC Spinbacks	NASA LaRC/ Chapman	Case Studies	Positive
NASA Southeast Alliance	NASA SE centers, RTTC	Surveys	Positive
NASA MSFC	NASA MSFC In-house	Surveys, Extrapolations	Positive
NIST Laboratories	NIST In-house (Tassey)	Cost-Benefit, IRR	Positive
NIST Laboratory Programs	NIST/ Link	Cost-Benefit	Positive
National Lab Tech Transfer	DOE Tech Partnerships Program	(1) Data analysis, (2) Cases	Positive
Tech Transfer, NREL	NREL/ Chapman, Moran	Survey, Extrapolations	Positive
Manufacturing Assistance, ORNL	ORNL/ CMT In-house	Survey, Extrapolations	Positive

Manufacturing extension	(1) GAO, (2) Census, (3) Individual centers	Surveys	(1) Negative, (2) Mixed, (3) Mostly Positive
DOD Laboratory Tech Transfer	DOD/OTT In-house	Survey	Process measures
Air Force Tech Transfer	Air Force/ Battelle, ESI	Lit search, Survey, Workshops, Interviews	Best practices
Govt. Lab Tech Transfer, Multi-agency	House Small Busn. Committee	Survey	Negative
Govt. Lab Tech Transfer, Multi-agency	GAO	Survey, Input/Output	Inconclusive
Govt. Lab Tech Transfer, Multi-agency	DOC (3 "Biennial" reports)	Surveys, Data analysis	Process measures
Govt. Lab Tech Transfer, Multi-agency	Interagency Committee	Establish Framework	Inconclusive
Govt. Lab Tech Transfer, Mid-Continent Region Labs	FLC/ Chapman	Survey	Positive
Govt. Lab Tech Transfer, Multi-agency	DOE, NSF, etc./ Bozeman et al	Surveys, Input-Output	Mixed
Govt. Lab Tech Transfer, Multi-agency	Papadakis		Mixed
Govt. Lab Tech Transfer, Multi-agency	NSF/ Geizler	Survey	Best practices
Govt. Lab, University Tech Transfer	NSF, DOE/ (IRI) Roessner, Bean	Surveys	Mostly positive
Govt. Lab, University, Intermediary Tech Transfer	DOC, CATI/ CITTI (Anderson)	Survey	Best practices
University Tech Transfer	(1) AUTM, (2) Individual universities	Surveys, public benefit analysis	(1) Positive growth, (2) Positive
University Tech Transfer, Southeastern Region	STC	Benchmarking	Benchmarking data, Best practices
Govt., University Tech Transfer	Carr	Lit Review, interviews	Best Practices
Laboratory Tech-based Economic Development	NASA MSFC, USASDC / University of Alabama	Survey	Positive
Laboratory, University Incubators	EDA/ NBIA, STC, ILGARD, UMich	Surveys, benchmarking	Positive impacts, best practices

Econometric Studies of R&D

In order to produce quantitative metrics, one way to analyze R&D outcomes (with technology transfer implicit within the process) involves using econometric techniques. Economists have been retrospectively estimating the impact of R&D on society since the 1950s.[95] The early econometric studies focused on R&D performed in corporate[96] and academic[97] settings, and by industry sectors, particularly agriculture.[98] Some of these studies explicitly examined technology transfer, but not government laboratory technology transfer.[99] As an analogy, examining corporate or academic impact is roughly comparable to estimating the economic impact of a laboratory (regardless of its technology transfer activities).[100]

Econometric studies fall into two categories: (1) studies of changes in national or regional productivity to measure the role of R&D and technological innovation; and (2) studies of social or private benefits, such as jobs created or consumer savings, based upon technological innovation. The first category involves statistical techniques that determine relationships between dependent variables (output, productivity, etc.) and independent variables (technology, patent data, skills, capital, labor, etc.).[101] The second category involves cost-benefit techniques that assess societal gains not attributable to profits in order to determine a rate of return. The

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[95]Robert Solow conducted the original classic work. See, for example: Robert M. Solow, "Technical Change and the Aggregated Production Function," *Review of Economics and Statistics* 39: 312-320, 1957.

[96]Edwin Mansfield, *Industrial Research and Technological Innovation: An Econometric Analysis*, Cowles Foundation for Research in Economics, Yale University, New York: W. W. Norton Books, 1968; Zvi Griliches, "Productivity, R&D, and Basic Research at the Firm Level in the 1970's," *American Economic Review* (March): 1986; Jeffrey Bernstein and M. Ishaq Nadiri, "Interindustry Spillovers, Rates of Return, and Production in High-Tech Industries," *American Economic Review Papers and Proceedings* 78: 429-434, 1988.

[97]Edwin Mansfield, "Academic Research and Industrial Innovation," *Research Policy* 20 (February): 1-12, 1991.

[98]See Zvi Griliches, "Research Expenditures, Edcation, and the Aggregate Agricultural Production Function," *American Economic Review* (December): 1964.

[99]Edwin Mansfield, Anthony Romeo, M. Schwartz, D. Teece, S. Wagner and P. Brach, *Technology Transfer, Productivity and Economic Policy*, New York: W. W. Norton Books, 1982.

[100]For example, Los Alamos National Laboratory in New Mexico comissioned a study of the laboratory's impact on the surrounding geographic region. New Mexico State University, the University of New Mexico and the DOE Regional Operations office conducted this study which found that, in 1995, the laboratory's funding of $1.2 billion accounted for nearly five percent of the state's economic activity, or $4.1 billion, and almost one-third of the economic activity in the three surrounding counties, or $3.4 billion of the region's estimated economic activity of $11.35 billion. See Los Alamos National Laboratory, *New Mexico Regional Impact Report*, May 1997.

[101]Zvi Griliches, editor, *R&D, Patents, and Productivity*, Chicago, Illinois: University of Chicago Press, 1984.

costs and benefits are calculated from changes in costs, prices, and sales through certain steps.[102] The late Edwin Mansfield is generally credited with developing this approach,[103] and it is closely related to another technique for analyzing R&D outcomes called bibliometrics.[104] Bibliometric tools involve counting scientific publications, technology patents, and citations. They show that 5,000 new scientific papers are published and 2,000 patents are issued each day, indicators of both R&D success <u>and</u> technology transfer. More intricate methods analyze science papers citing papers, technology patents citing patents, or linkage patents citing papers.

A 1995 Council of Economic Advisors paper[105] and other papers[106] compared key studies by Mansfield and others. These reviews found that the mean private rate of return for a technological innovation is twenty to thirty percent, and the social rate of return is almost fifty percent.[107] Over a series of his own studies, Mansfield found a median rate of private return of 25 percent, and a median rate of social return of seventy percent.[108] Because econometric studies

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[102]The steps are: Determine gains to producers and consumers, determine the amount attributable to an innovation, subtract out losses, estimate labor market impacts and externalities, discount future benefits in order to determine net present value, and quantify the rate of return.

[103]The National Science Foundation supported Mansfield's early work in developing this approach through seventeen case studies reported in two volumes. It was eventually summarized in: Edwin Mansfield et al, "Social and Private Rates of Return from Indusrial Innovation," *Quarterly Journal of Economics* (May): 221-240, 1977. Two other NSF-supported studies in this area are: Foster Associates, Inc., *A Survey of Net Rates of Return on Innovation*, Three Volumes, National Science Foundation, May 1978; and, Robert R. Nathan Associates, Inc., *Net Rates of Return on Innovation*, Three Volumes, National Science Foundation, October 1978.

[104]For example, a study by CHI Research, Inc. examined patents in the 1993-94 and 1987-88 time frames, and found a tripling of the industry linkages to government R&D (as opposed to industrial R&D) from the early time frame to the later one; more than seventy percent of the key industry patent citations came from public science performed at universities, government laboratories and other public agencies. In general, this shows that technology is being transferred effectively from government laboratories or government-funded institutions. See Francis Narin, et al, "The Increasing Linkage Between U.S. Technology and Public Science," *AAAS Science and Technology Policy Yearbook 1998*, Albert H. Teich et al, editors, American Association for the Advancement of Science, ISBN 0-87168-611-2, p. 101-121, 1997. Bibliometric studies of R&D outcomes date back to the 1960s, when the Defense Department sponsored the Institute for Defense Analyses and RAND to retrospectively measure the increase in cost-effectiveness of defense systems assignable to DOD-funded research and technology. The study, called Project Hindsight (1969), found that technological advances were not based upon basic science. About the same time, the National Science Foundation sponsored the "Traces" study (*Technology in Retrospect and Critical Events in Science*) by the Illinois Institute of Technology Research Institute (1969) which countered the other study's claim. NSF still sponsors traces-type studies through SRI International.

[105]Council of Economic Advisors, *Supporting Research and Development to Promote Economic Growth: The Federal Government's Role*, October 1995.

[106]See, for example, N. Terleckyj, *Effects of R&D on the Productivity Growth of Industries: An Exploratory Study*, Washington, D.C.: National Planning Association, 1974.

[107]M. Ishaq Nadiri, *Innovations and Technological Spillovers*, National Bureau of Economic Research (NBER) Working Paper Series, Cambridge, Massachusetts: NBER, Working Paper no. 4423, August 1993.

always produce these strong positive correlations between technology and the economy,[109] their use can be justified to retrospectively measure an R&D program or to develop related general policies. However, they produce estimates rather than precise impacts, so they are not necessarily appropriate for making R&D funding decisions.[110]

Benefit-cost econometric models have been used successfully by certain government laboratories to measure the impact of their R&D and technology transfer activities. The agencies and programs that have done the most work in terms of using econometric and benefit-cost analyses to evaluate laboratory impact include: the laboratories comprising the National Institute of Standards and Technology (NIST), the NASA headquarters technology transfer program, and certain NASA R&D programs such as the Space Program. As will be pointed out, some of this work has explicitly focused on technology transfer activities, and some of the evaluation work has implicitly included technology transfer. Therefore, the next section begins with NIST and NASA and proceeds to other agencies and approaches.

Before proceeding to the next section, it should be noted that the only multi-agency R&D funding program that involves explicit technology transfer from government laboratories (or other R&D institutions) is the Small Business Technology Transfer Program (STTR) which was first implemented in the mid-1990s. But it has been too soon to conduct serious STTR economic impact evaluations. The Defense Department's Technology Reinvestment Project (TRP) also funded some government-industry partnerships, thereby explicitly involving technology transfer. However, DOD has not evaluated the early TRP projects since this program was cut from the budget. It is also noted that benefit-cost approaches have been used to evaluate the R&D performed through technology funding programs at the state level. However, as with federally-funded R&D, state-funded R&D programs may or may not involve government laboratory technology transfer.[111] In any case, what state R&D programs <u>do</u> have in common with government laboratory technology transfer is the difficulty in measuring their ultimate economic impact.

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[108]Edwin Mansfield, "How Economists See R&D," *Harvard Business Review* 59 (6/ November-December): 98-106, 1981.

[109]Edwin Mansfield, "Social Returns from R&D: Findings, Methods and Limitations," *Research/ Technology Management* (November-December), 1991.

[110]Richard L. Chapman, "Alternative Methods to Evaluate Technology Transfer," *Technology Commercialization and Economic Growth: Technology Transfer Society 20th Annual Meeting Proceedings, July 16-19, 1995, Washington, D.C.*: 1-9, 1995; see also, Richard H. White with An-Jen Tai, et al, *The Economics of Commercial-Military Integration and Dual-Use Technology Investments*, Alexandria, Virginia: Institute for Defense Analyses, IDA Paper P-2995, June 1995, reprinted 1997.

[111]The commercializing firms may receive funds to perform R&D themselves rather than transfer it from a laboratory. See Irwin Feller and Gary Anderson, "A Benefit-Cost Approach to the Evaluation of State Technology Development Programs," *Economic Development Quarterly* 8 (2/May): 127-140, 1994.

Evaluating Government Technology Transfer

NIST Programs, Laboratories Focused on Impact Evaluation

A 1994 report from the National Institute of Standards and Technology (NIST) discusses how each of NIST's four program areas set priorities, evaluate performance, and measure economic impact.[112] NIST's four major program areas are: (1) the Advanced Technology Program, (2) Manufacturing Extension Partnership, (3) the Malcolm Baldrige National Quality Award Program (not a technology transfer program), and (4) the various NIST laboratories that perform R&D and technology transfer. The report stated that metrics could not be reduced to simple formulas yielding unambiguous, quantitative answers because judgments are inherent to the process and must be guided by both qualitative and quantitative data. Consequently, a companion report presented case studies describing the industrial impacts of these four program areas.[113]

NIST Laboratory Research and Tassey Econometrics: Laboratory research is the NIST area with the most depth as far as impact studies. NIST's Economist, Gregory Tassey, produced a 1996 report which examined the impact of the NIST laboratories.[114] In this report, as well as a book by Tassey,[115] the laboratory infrastructure was labeled "infratechnology." The report stated that measuring the economic impact of laboratory research projects requires both quantitative (eg., sales, reduced time to market) and qualitative metrics. He identified NIST's qualitative metrics as: effects on standardization, R&D results, and improved collaboration with industry. NIST's most common methods for measuring economic impacts are: (1) benefit-cost ratios and (2) internal or social rates of return. The report noted that in comparing NIST with similar private-sector research and technology investments, the NIST research projects produced "estimated social rates of return above estimates for private-sector innovations."[116] A follow-up book by Tassey carried this theme further, covering infratechnology as well as standardization and other mechanisms, and provided R&D policy impact assessment methods.[117]

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[112]Department of Commerce, National Institute of Standards and Technology, *Setting Priorities and Measuring Results at the National Institute of Standards and Technology*, January 1994.

[113]National Institute of Standards and Technology, *NIST Industrial Impacts: A Sampling of Successful Partnerships,* NIST Special Publication 872, First printing September 1994, revised February 1996.

[114]Tassey, Gregory, *Rates of Return from Investments in Technology Infrastructure*, National Institute of Standards and Technology, Program Office, 96-3 Planning Report, June 1996.

[115]Gregory Tassey, *Technology Infrastructure and Competitive Position,* Norwell, Massachusetts: Kluwer Academic Publishers, 1992.

[116]Ibid, 1996.

[117]Gregory Tassey, *The Economics of R&D Policy*, Westport Connecticut: Quorum Books, ISBN 1-56720-093-1, 1997.

NIST Laboratory Research and Link Econometrics: Throughout the 1990s, another economist, Albert Link produced a series of economic impact studies for NIST in various technology and industrial sectors related to NIST laboratory research such as optical fibers, semiconductors, and electromagnetic interference.[118] A 1996 book by Link on evaluating public-sector R&D brings together seven NIST benefit-cost cases, although he emphasized several times that the purpose was not to compare across cases or projects because benefit-cost methodologies are not useful for that purpose.[119] The benefit-cost evaluations documented ratios ranging from 7-to-1 up to 1,041-to-1 for the laboratory research, as well as some preliminary findings for NIST's ATP program.

There are certain steps involved in calculating cost-benefit ratios. Computing the cost portion generally involves obtaining program budgets over a period of time, and many of the Link analyses were calculated or projected back to the early 1980s. Computing benefits involves questioning industry users according to a survey instrument of open-ended questions which may uncover both tangible and intangible responses. Where the benefits (eg., sales revenue or other economic gains) or savings are not clear-cut, economists empirically estimate the value of non-market-type goods and services[120] based upon survey responses. These are, in other words, social benefits not attributable to profits or other monetary amounts. Often this involves extrapolating into the future or the past to estimate non-market values. Sometimes it must involve measuring benefits indirectly based upon an attribute of the output (such as a citation or patent count). These subjective or speculative aspects of an economist's work are said to be determined through "informed opinion" or by developing a consensus among the respondents ("peer evaluation").[121]

[118]This series of NIST planning reports includes: "Economic Impacts of NIST-Supported Standards for the U.S. Optical Fiber Industry: 1981-Present" (1991); "Economic Impact on the U.S. Semiconductor Industry of NIST Research in Electromigration" (1991); "Economic Impact of NIST Research on Electromagnetic Interference" (1991); "An Evaluation of the Economic Impacts Associated with the NIST Power and Energy Calibration Services" (1995); "An Economic Assessment of the Spectral Irradiance Standard" (1995); and "Economic Evaluation of Radiopharmaceutical Research at NIST" (1997).

[119]Albert N. Link, *Evaluating Public Sector Research and Development*, Westport, Connecticut: Praeger Books, ISBN 0-275-95368-8, 1996.

[120]Often the case, he points out, because "one of the justifications for public sector involvement is that the market has failed to provide sufficient quantities of such goods and services."

[121]NIST supported Link to develop guidelines for the NIST program and project managers to familiarize them "with the motivation for and mechanics of an economic impact assessment." The guidelines provide step-by-step explanations for conducting and interpreting economic impact assessments on either completed or ongoing research projects. They discuss both the internal rate of return and the benefit-cost econometric models, the latter being more easily understood by both policymakers and public sector R&D managers, according to Link. They also explain the difference between internal rate of return and return on investment, and provide equations to compute net present values and other values. See, Albert N. Link, *Economic Impact Assessments: Guidelines for Conducting and Interpreting Assessment Studies*, National Institute of Standards and Technology, Program Office, Planning Report 96-1, May 1996.

The Link method incorporated technology transfer, in the sense that technology transfer activities were included under costs. Costs are categorized in various ways (e.g., push, industry pull). Where relevant, the technology transfer costs were included under the category of tangible "push" costs. However, not all of the evaluated NIST research projects involved explicit technology transfer. In most of the NIST laboratory cases, technology transfer was subsumed under R&D costs.

NASA Technology Utilization Assessment Began Early-on

The National Aeronautics and Space Administration (NASA) has a long history of program evaluation because the 1958 Space Act charged NASA with performing technology transfer. The NASA headquarters Technology Utilization office sponsors publications and other technology transfer-related activities such as publications and intermediaries.[122] The NASA "field centers" (laboratories) each have technology transfer offices which implement "Space Act Agreements" (or CRADAs).

NASA TU Program Econometrics: In the late 1970s, Congress required a cost-benefit study of NASA technology transfer.[123] In order to assess the feasibility of conducting such a study and to compare alternative analysis methods, the NASA Technology Utilization (TU) office initiated several studies through the Denver Research Institute and Mathematica, Inc. Mathematica's Mathtech Division studied the value added by the technology transfer activities of the NASA TU office by quantifying the economic benefits of secondary applications of NASA-related R&D.[124] Mathematica selected four specific technology areas[125] to analyze because: (1) data were available, (2) NASA's role was widely acknowledged, and (3) the benefits were anticipated to be relatively large. The researchers said they were conservative in their calculations, yet they found the total benefits of the four cases were about $7 billion, more than twice NASA's annual budget at the time.

The Denver Research Institute (DRI) studied the cost-benefit of specific NASA activities funded by the TU office,[126] including: (1) the monthly trade journal *Tech Briefs*, (2) Industrial

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[122]NASA sponsors regional technology transfer centers, originally called "industrial applications centers," in each of the regions delineated by the Federal Laboratory Consortium.

[123]Fiscal year 1977 and 1978 House of Representatives budget hearings and NASA Authorization Report.

[124]Mathematica, Inc., Mathtech Division, *Quantifying the Benefits to the National Economy from Secondary Applications of NASA Technology*, Washington, D.C.: National Aeronautics and Space Administration, NASA Contract Report CR-2673/CR-2674, June 1975, revised March 1976; see also, Robert J. Anderson et al, *A Cost-Benefit Analysis of Selected Technology Utilization Office Programs*, Princeton, New Jersey: Mathtech, 1977.

[125]The four areas were: cryogenic multi-layer insulation materials, integrated circuits, gas turbines in electric power generation, and computer programs for structural analysis (called NASTRAN).

[126]Johnston, F. Douglas, with Martin Kokus, Jana Henthorn and Stephen Quist, *NASA Technology*

Applications Centers, (3) the Computer Software Management and Information Center (COSMIC), and (4) applications teams. DRI measured program costs and program benefits, and concluded that the benefit-cost ratio for the total TU program was at least 6-to-1, with the individual ratios for the four TU program elements ranging from 3-to-1 up to 26-to-1. In 1979, DRI incorporated into a summary report: the results from a 1976 study of *Tech Briefs*, a 1977 study of the other program elements, and the 1976 Mathematica study results.[127]

NASA Space Program Econometrics: In the 1980s, NASA sponsored studies of the value added to the economy by the agency's overall space program, but they did not explicitly address the technology transfer role. Two studies by the Midwest Research Institute[128] showed paybacks on the NASA R&D investment ranging from 6-to-1 and 9-to-1. A Chase Econometrics Associates study showed paybacks of over 14-to-1.[129] Besides not addressing technology transfer, these studies also did not take into account any intangible, non-quantifiable factors.

NASA TU Program Elements - Chapman Survey: In more recent years, NASA technology transfer evaluation has changed to survey approaches. In the late 1980s, Chapman Research Group explored successful technology applications highlighted in NASA's annual publication called *Spinoff*.[130] The purpose was to identify benefits resulting from the applications highlighted in the publication each year, and to quantify those benefits where possible. Richard Chapman and his team examined 259 technologies through 600 telephone interviews (based upon some 3,000 calls) with 400 companies over eight months. The resulting 1989 report documented over $21.6 billion in economic benefits and countless intangible benefits.

As a companion piece to the *Spinoff* survey, Chapman followed up with a "characterization study" describing the lessons learned from doing that study,[131] particularly the

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Utilization Program: A Cost-Benefit Evaluation, Prepared for Office of Technology Utilization, National Aeronautics and Space Administration Denver, Colorado: Denver Research Institute, Contract NASW-3021, December 1979.

[127]F. Douglas Johnston and Martin Kokus, *NASA Technology Utilization Program: A Summary of Cost-Benefit Studies*, Prepared for Office of Technology Utilization, National Aeronautics and Space Administration, Denver, Colorado: Denver Research Institute, Industrial Economic Division, NASA Contract NASW-3021, December 1977.

[128]Midwest Research Institute, *Economic Impact and Technological Progress of NASA Research and Development Expenditures*, Three Volumes, Kansas City, Missouri: Midwest Research Institute, NASA Contract Report NASA-CR-195946, September 1988. See also, Midwest Research Institute, *Economic Impact of Stimulated Technological Activity*, Three Volumes, Kansas City, Missouri: Midwest Research Institute, October 1971.

[129]Michael K. Evans, *The Economic Impact of NASA R&D Spending*, Bala Cynwyd, Pennsylvania: Chase Econometrics Associates, Inc., April 1976.

[130]Richard Chapman, Loretta C. Lohman and Marilyn J. Chapman, *An Exploration of Benefits from NASA Spinoff*, Littleton, Colorado: Chapman Research Group, Inc., Contract 88-01 with NERAC, Inc., June 1989.

[131]Loretta C. Lohman and Richard L. Chapman, *"Lessons Learned" About the Collection of Spinoff*

difficulties in retrospectively collecting data for technology transfer events that occurred ten or twelve years earlier. Also, they were faced with inadequate records of company names, persons involved, addresses, telephone numbers, and even the technologies. Since that study, Chapman's consistent message for any technology transfer program has been to integrate measurement early-on into program activities so that it becomes a regular and systematic aspect of the operation. Another Chapman paper reiterated the message not to over-rely on quantitative measures.[132] He concluded, " . . .it is important to continually include some evaluation of quality *and* to be cautious about over dependence upon indications just because they are easily quantified -- ie., avoid the attitude that . . .if you can't count it, it doesn't count."[133] He said the "chemistry" of the collaboration, commitment of top management, closeness of "fit" to the laboratory's technology and mission are key elements that numbers and dollars do not reflect. Chapman reiterated these two themes (about systematizing measurement and not over-relying on quantitative measures) in later papers, as well.[134] A 1994 paper compared the lessons learned from doing program evaluation studies with NASA, the Department of Agriculture, and the DOE National Renewable Energy Laboratory.[135]

The University of Tennessee Space Institute "characterized" successful companies featured in NASA's *Spinoff* publication from 1984 to 1991.[136] By surveying 287 companies with a 29 percent response rate, Brett Pichon and Bobbie Woodard developed a profile of characteristics for a "successful technology transfer company" (the company is involved in manufacturing, has fewer than 150 employees, etc.). The Tennessee Valley Authority and NASA's Marshall Space Flight Center (in Alabama) supported this study.

Benefits Data, Littleton, Colorado: Chapman Research Group, Inc., NERAC Contract #87-01, March 1989.

[132]Richard Chapman, "Measuring Technology Transfer Success: Overcoming the 'If You Can't Count it, It Doesn't Count' Syndrome," *Technology Transfer Society 18th Annual Meeting Proceedings, June 26-29, 1993, Ann Arbor, Michigan*: 13 - 19, 1993.

[133]Ibid.

[134]Richard L. Chapman, "Alternative Methods to Evaluate Technology Transfer," *Technology Commercialization and Economic Growth: Technology Transfer Society 20th Annual Meeting Proceedings, July 16-19, 1995, Washington, D.C.*: 1-9, 1995.

[135]Richard L. Chapman, "Case Studies in the Tracking and Measuring of Technology Transfer," *Technology Transfer Partnerships: Technology Transfer Society 19th Annual Meeting Proceedings, June 22 - 24, 1994, Huntsville, Alabama*, Kenneth E. Harwell, Kathy Wagner and Carl Ziemke, editors: 164 - 171, 1994.

[136]University of Tennessee Space Institute and the Tennessee Valley Aerospace Region, *Technology Transfer Research Project: Identification and Analysis of the Factors Present in Successful Technology Transfer Cases*, Prepared by Brett Pichon and Bobbie Woodard, Sponsored by the Tennessee Valley Authority, June 17, 1993.

Individual NASA Field Centers Initiated Projects

NASA Langley - Bush Study: A study of NASA technology transfer by Lance Bush started out by examining all the field centers, but zeroed in on the NASA Langley Research Center in Virginia.[137] Bush first compared overall NASA license royalties with those of U.S. universities and determined that NASA would have ranked 67th among them. He also performed a statistical analysis to identify the strength of correlations between NASA input, intermediate, and outcome measures. The quantitative input measures he obtained by interviewing NASA Langley researchers on their awareness, attitudes and perceptions of technology transfer; the outcome measures were the quantitative royalty figures. The somewhat varying correlations were explained by three case studies that showed the details of technology transfer can't be explained by only a simple royalty measure.

NASA Langley - Spinbacks Study: Richard Chapman studied the concept of "spinbacks"[138] for the NASA Langley Research Center.[139] In order to test the feasibility of undertaking a comprehensive study of the value of spinback, he examined nine cases. The exploration demonstrated that the spinback phenomenon is real, can be documented, and deserves attention.

NASA Marshall Surveys: Several news articles referenced an inaccessible "Fall 1994 Marshall report" with numbers related to the Marshall Space Flight Center. *Technology Transfer Business* and *FLC Newslink* both stated that a Marshall survey of 809 companies covering eighteen months generated 283 responses from firms receiving technical assistance and sixteen responses from firms with formal industry agreements with the Marshall center; surveys were mailed to 18 of 56 partners.[140] This survey indicated 665 jobs created or saved, 69 new products, $47.2 million increased sales, $10.2 million increased investment, and $11.5 million cost savings. The Marshall analysts extrapolated to the sample of 809 by applying Standard Industrial Classification (SIC) codes to numeric multipliers used by the Bureau of Economic Analysis in the census. This produced the following figures: 5,344 jobs created or saved, 182 new products, and $358.4 million in increased investment, an economic impact of 60-to-1. The *Technology Transfer Business* article noted that Marshall's extrapolations "raised eyebrows," and another news article highlighted the same metrics without mentioning the extrapolated numbers.[141] The

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[137]This study was originally produced as Bush's doctoral dissertation at Pennsylvania State University; Lance B. Bush, *An Analysis of Technology Transfer at NASA*, NASA Technical Memorandum 110270, Hampton, Virginia: Langley Research Center, July 1996.

[138]The flow back to laboratories of technical advantage from technology transfer activities.

[139]Richard L. Chapman, "An Exploration of the 'Spinback' Phenomenon," *Journal of Technology Transfer* 19/3-4 (December): 78-86, 1994.

[140]Randy Barrett, "Will Metrics Really Measure Up?" *Technology Transfer Business* (Spring): 34-36, 1995. See also "Marshall Tech Transfer Generates Thousands of Jobs," *The FLC Newslink* (March): 2, 1995.

[141]"NASA's Marshall Center Generates 5,300 Jobs," *Spotlight on Technology*, NASA Southeast Regional

Marshall center promulgated even other metrics on a state-by-state basis.[142] One source stated, "A nonresponse rate of 61% combined with a non-random sample brings serious concern to the extrapolation of the results to the sample population . . .In addition to the sampling issues of this study, there is some question as to the validity of the multiplying factors."[143]

NASA Southeast Alliance Surveys: Besides the Marshall Space Flight Center in Alabama, the other Southeast region field centers are the Stennis Space Center in Mississippi and the Kennedy Space Center in Florida. Together, and with assistance from the regional technology transfer center in Florida, they are known as the Southeast Alliance for Technology Transfer. In the mid-1990s, NASA's southeastern region promulgated a variety of metrics related to the field center technology transfer programs in that region:

- A 1995 paper indicated the three southeastern centers sent questionnaires on technology transfer to 1,343 firms, with 508 (38 percent) responding.[144] The findings show that the centers' technology transfer activities in 1993 and 1994 created or saved over 7,400 jobs and provided over $185 million in direct economic benefits, with an estimated overall impact to the economy of over $654 million.

- The introduction to the Marshall Center's *1995 Research and Technology Report* stated that "approved surveys" showed, in a recent three-year time period, the three centers projected 10,500 jobs created/saved, 459 new products, and $988 million in economic impact.[145]

- The NASA publication *Tech Briefs* stated that a survey by the three centers indicated 13,200 jobs created or saved, 775 new products, and $1.2 billion in value to American businesses.[146]

Apparently, the Southeast Alliance study was an update of the Marshall study, and it was said to

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Technology Transfer Center & Southeast Regional Federal Laboratory Consortium (January/February): 5, 1995.

[142]For example, since 1993, Marshall's impact on the state of Tennessee was: 1,547 jobs created or saved and 63 new products, with $171 million being the value of the jobs and products. See "NASA, Tennessee Agree to Renew Technology-Transfer Agreement," *McGraw-Hill's Federal Technology Report* (August 29): 5-6, 1996.

[143]Bush, p. 52, 53.

[144]Harry Craft, W. Sheehan and A. Johnson, "NASA's Southeastern Regional Initiative in Technology Transfer and Commercialization," *46th International Astronautical Congress, October 2-6, 1995, Oslo, Norway*, American Institute of Aeronautics and Astronautics, Inc., IAA-95-IAA.1.2.08, 1995.

[145]Marshall Space Flight Center, *1995 Research & Technology Report*, Introduction: 2, 1995.

[146][untitled], *NASA Tech Briefs* (July): 23, 1996.

have the same nonresponse bias flaw.

Department of Energy Evaluation Got Caught in Politics

DOE Survey: In terms of in-house, system-wide evaluation of technology transfer, the Department of Energy (DOE) was a leader among the federal departments and agencies. The DOE Technology Utilization Office conducted a series of regional "partnership" meetings to gain feedback about the type of information industry would be willing to share with the government to help evaluate technology transfer, particularly CRADAs. A 1994 progress report[147] discussed how the department was developing a database to record customer satisfaction measures, as well as performance and effectiveness measures. The system would track indicators from partnership milestones to economic indicators (such as the number of jobs created, companies formed, new product sales, and costs avoided). It was designed to prevent unauthorized access of proprietary and confidential information.

Later in 1994, as the political fervor rose, members of Congress and the Congressional Budget Office raised concerns about whether the extensive DOE investment in applied R&D programs[148] was cost-effective. In response, DOE's Technology Partnerships Office[149] contracted for a report on DOE R&D award-winners.[150] Data on 268 award-winners[151] indicated that 51 percent of the technologies were transferred to the private sector; for the 137 technologies that were transferred, 153 private sector partners were identified. The most common transfer mechanism was licensing (followed by exchange of data and software, and contracts and subcontracts). Also in 1995, DOE produced a series of "success stories" describing 61 technologies developed by its applied R&D programs and the economic benefits (eg., energy savings) of each technology.[152]

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[147]Department of Energy, *Our Commitment to Change: A Year of Innovation in Technology Partnerships*, September 1994.

[148]About $1.65 billion in fiscal year 1995.

[149]Officially, this office was the Office of the Deputy Under Secretary for Technology Partnerships and Economic Competitiveness, known as the Technology Partnerships Office, and previously called the Technology Utilization Office.

[150]Department of Energy, *The Transfer and Commercial Impact of the U.S. Department of Energy's Award-Winning Technologies*, Prepared for Office of the Deputy Under Secretary for Technology Partnerships, U.S. Department of Energy, Prepared by Oak Ridge Institute for Science and Education, Training and Management Systems Division, February 1995.

[151]For 36 years, *R&D Magazine* has conducted its annual R&D 100 Awards program. The awards are informally known as the "Nobel Prizes of Applied Research." DOE usually receives a large portion of these awards each year, in comparison to other federal departments and agencies.

[152]Department of Energy, *Success Stories: The Energy Mission in the Market Place*, 1995.

GAO Response: In response to this, GAO was somewhat critical of the *Success Stories* report's methodologies in testimony before Congress.[153] GAO reviewed fifteen of the 61 cases and found problems with eleven of them, ranging from mathematical errors to "unsupported links between the benefits cited and DOE's role."[154] GAO said the report described the successes of only a small percentage of DOE programs, and did not document the amount of money spent on the technologies. According to GAO, more rigorous cost-benefit analyses would have been appropriate. GAO's premise is that applied research should result in product sales, and program costs should be less than sales in order to be cost-effective.

This elicited a strong response from Congressman George Brown of the House Science Committee through a four-page letter to the Comptroller General.[155] Meanwhile, DOE continued developing its metrics system for the national laboratories.[156] However, Congress disbanded the DOE Technology Partnerships Office in 1996.

Individual DOE Laboratories Initiated Projects

NREL Survey: In spite of all this fervor at the DOE headquarters level, the individual DOE laboratories worked to develop metrics on their own. For example, the National Renewable Energy Laboratory (NREL) in Colorado contracted with Chapman Research Group to assess the benefits of technology transfer to successful NREL collaborators.[157] In 1994 and 1995, Richard Chapman and Dana Moran interviewed NREL partners involved in licenses, CRADAs, contracts, technical assistance, informal collaboration, reimbursable work-for-others, post-doctoral research, and NREL conferences. Of 156 partners interviewed, 66 provided estimates of sales (nearly $690 million) or savings (more than $20 million) resulting from their association with NREL and its technologies. They also measured benefits in intangible terms, resulting in "an array" of benefits to the partners.

[153] General Accounting Office, *Energy R&D: Observations on DOE's Success Stories Report*, Testimony before the Subcommittee on Energy and Environment, Committee on Science, House of Representatives, GAO/T-RCED-96-133, April 17, 1996. See, also, General Accounting Office, *DOE's Success Stories Report*, GAO/RCED-120R, April 15, 1996.

[154] Ibid.

[155] House of Representatives, Committee on Science, Letter to the Honorable Charles Bowsher, Comptroller General of the United States from Ranking Democratic Member George E. Brown, Jr., April, 17, 1996.

[156] Moira M. Shea, "Technology Partnerships: Measuring Performance, The Integrated Technology Transfer System," *Technology Commercialization and Economic Growth: Technology Transfer Society 20th Annual Meeting Proceedings, July 16-19, 1995, Washington, D.C.*: 35-39, 1995.

[157] Richard Chapman and Dana Moran, "Measuring the Results of Partnerships for Technology Transfer: Lessons Learned at the National Renewable Energy Laboratory," *Technology Transfer Models for Growth and Revitalization: Technology Transfer Society Proceedings, 21st Annual Meeting, July 21-23, 1996, Cleveland, Ohio,* William Grimberg, Sally Kickel and Lydia Skapura, editors: 145-154, 1996.

Oak Ridge Manufacturing Assistance Evaluation: Certain DOE laboratories, such as Oak Ridge National Laboratory, have major technical assistance[158] initiatives in the manufacturing area. The Oak Ridge Center for Manufacturing Technology offers three services to its customers: rapid development and deployment of products and processes, problem-solving, and skills training. The center provides these services through several types of mechanisms, including CRADAs, technical assistance agreements, work-for-others, and user facility agreements. A 1995 booklet describes how the center has implemented a system for setting priorities and measuring results.[159] Accordingly, the center surveyed two hundred clients and received 140 responses. Extrapolating these responses to the eight hundred cases of assistance showed that the economic return (from a $3-4 million investment) could be measured in the "tens of millions of dollars," according to the center's Direct Assistance Manager.[160]

Evaluation of these laboratory-based manufacturing assistance programs have much in common with the federal-state Manufacturing Extension Partnership (MEP) program operated by NIST. The MEP centers have been evaluated by both the federal and state levels. At the state level, Michigan, New York and Georgia can be cited as interesting examples. Evaluators in Georgia developed a benefit-cost model, and found a combined net public and private benefit-cost ratio of 1.2-to-2.7.[161] In Michigan, the Industrial Technology Institute provides a Performance Benchmarking Service for the extension center's client firms so they can benchmark themselves against control groups of non-assisted firms (from which data has been collected).[162] The New York evaluation used state employment records to provide a control group.[163] In terms of focussing on technical assistance as a technology transfer mechanism, another group of providers of technical assistance include the regional technology transfer

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[158]As noted, technical assistance is a technology transfer mechanism.

[159]Department of Energy, *Setting Priorities and Measuring Results*, Oak Ridge Centers for Manufacturing Technology, 1995.

[160]David Kramer, "Gauging Tech Transfers is Tough, DOE's Oak Ridge Operator Finds," *McGraw-Hill's Federal Technology Report* (June 23): 11-12, 1994.

[161]Philip Shapira and Jan Youtie, *Assessing GMEA's Economic Impacts: Towards a Benefit-Cost Methodology*, GMEA Evaluation Working Paper E9502, Atlanta, Georgia: Georgia Tech Economic Development Institute, 1995.

[162]This requires ongoing data collection, but it helps identify areas for program improvement; the non-assisted firms also receive benchmarking feedback in return for their data, which generates additional positive changes. See Kristin Dziczek, Daniel Luria and Edith Wiarda, "Assessing the Impact of a Manufacturing Extension Center," *Technology Transfer Metrics Summit Proceedings*, Sally A. Rood, editor, Chicago, Illinois, Technology Transfer Society: 186-198, June 1997.

[163]Nexus Associates, Inc., *Evaluation of the New York Manufacturing Extension Partnership*, Final Report, Prepared for the New York State Science and Technology Foundation/ Empire State Development, Gen#95037, March 18, 1996.

centers, but very little has been done in the way of evaluating their activities.[164]

DOD Measured Laboratory Transfer, Examined Programs

Office of Technology Transition Report: The DOD Office of Technology Transition, created in the early 1990s at the level of the Office of the Secretary of Defense, encompasses technology transfer in the military service laboratories. The 1993 National Defense Authorization Act requires the office to report annually to Congress on its survey of defense laboratories and implementation of its Federal Defense Laboratory Diversification Program. The offices'1994 report[165] highlighted, for example, the following for fiscal year 1992: 246 CRADAs, 890 patent applications filed, nineteen licenses, and $274,000 in royalty income.

Battelle Benchmarking of Air Force: At the individual service level, the Air Force sponsored a broad-ranging study of CRADAs and commercialization in the early 1990s. The Battelle team conducting the study carried out a literature search, a survey, benchmarking interviews, and two workshops in order to gather information for a publication on best practices in partnering with the military.[166]

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[164]A literature review of technology transfer to small firms said there is a "near total lack of information" on the subject of small firms and federal laboratory technology transfer, and few studies of the role of intermediaries in this process. (Mt. Auburn Associates, *Technology Transfer to Small Manufacturers: A Literature Review*, Final Report, Submitted to U.S. Small Business Administration, Submitted by Mt. Auburn Associates, Inc. with Regional Technology Strategies, Inc. Somerville, Massachusetts, August 1995.) The NASA-funded regional technology transfer centers (RTTCs), who facilitate technology transfer between government laboratories and industry, are examples of publicly-supported intermediaries. Nan Muir analyzed success criteria for public intermediaries by surveying RTTCs, laboratories, and industry to determine the validity of quantitative metrics to measure the outcomes of their activities. (See Nan Muir, "Measuring Technology Transfer Success: A Study of Intermediary Agency Evaluation," *Technology Commercialization and Economic Growth: Technology Transfer Society 20th Annual Meeting Proceedings, July 16-19, 1995, Washington, D.C.*: 17-26, 1995.) She found a range of answers suggesting potential future work in this area. Other than this, there are few evaluations of public or private intermediaries for laboratories and universities. Private intermediaries working with universities (and occasionally with government laboratories) are more commonly known as "technology brokers." They market and license technologies, and sometimes take equity positions in new firms. This field is comprised of several large technology brokering firms of several hundred persons each, and hundreds of small brokerage outfits usually comprised of one or two partners who specialize in specific technology areas. There are few studies of private intermediaries.

[165]Department of Defense, Director of Defense Research and Engineering, *Survey of Laboratories and Implementation of the Federal Defense Laboratory Diversification Program*, February 1994.

[166]John Lesko and Michael Irish, *Technology Exchange: A Guide to Successful Cooperative R&D Partnerships*, Battelle and Economic Strategy Institute, 1995. The second edition appeared as follows: John Lesko, Phillip Nicolai and Michael Steve, *Technology Exchange in the Information Age: A Guide to Successful Cooperative R&D Partnerships*, Columbus, Ohio: Battelle Press, 1995.

Congress and GAO Examined Technology Transfer, Multi-Agency

House Committee Small Business Survey: In the late 1980s, the House Committee on Small Business asked its subcommittee staff to investigate the role of government laboratories in the competitiveness of U.S. firms. To accomplish this, the staff surveyed key agencies on technology transfer. They found that government technology transfer efforts were "under-staffed, under-directed, and only marginally focused."[167] This resulted in frustrated government scientists and discouraged businesses, and licensing revenues representing "a return on research investment of only .00005 percent."[168]

GAO Surveys: The General Accounting Office began evaluating technology transfer by monitoring agency and laboratory implementation of the earlier 1980 Stevenson-Wydler Technology Innovation Act.[169] In 1988, GAO began preparing for a major analysis of implementation of the 1986 Federal Technology Transfer Act,[170] and conducted a somewhat controversial evaluation through a sixty-page survey sent to 297 laboratories.[171] GAO produced a preliminary report on its pilot questionnaire in 1989,[172] and testified on more than one occasion regarding progress in the evaluation.[173] However, the final report and testimony were not that different from the preliminary report.[174] Evidently, a full report never was accepted for

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[167] House of Representatives, Committee on Small Business, Subcommittee on Regulation, Business Opportunities and Energy, *Technology Transfer Obstacles in Federal Laboratories: Key Agencies Respond to Subcommittee Survey,* Washington, D.C.: U.S. Government Printing Office, Committee Print 101-3, March 1990.

[168] Ibid.

[169] General Accounting Office, *Federal Agencies' Actions to Implement Section 11 of the Stevenson-Wydler Technology Innovation Act of 1980,* GAO/RCED-84-60, August 24, 1984.

[170] General Accounting Office, *Technology Transfer: Constraints Perceived by Federal Laboratory and Agency Officials*, Briefing Report to the Chairman, Committee on Science, Space and Technology, House of Representatives, GAO/RCED-88-116BR, March 1988.

[171] Some of the controversy over this questionnaire centered around its length and level of detail. Some were upset that it required onerous record-keeping requirements by technology transfer personnel, such as documenting every phone call.

[172] General Accounting Office, *Technology Transfer: Implementation Status of the Federal Technology Transfer Act of 1986,* Report to Congressional Requesters, GAO/RCED-89-154, May 1989.

[173] General Accounting Office, *Implementation Status of the Federal Technology Transfer Act of 1986*, Statement of John M. Ols, Jr., Director, Resources, Community, and Economic Development Division, Before the Subcommittee on Science, Research, and Technology, Committee on Science, Space, and Technology, House of Representatives, GAO/T-RCED-89-47, June 1, 1989; General Accounting Office, *Implementation of the Technology Transfer Act: A Preliminary Assessment*, Statement of Carl E. Wisler, Director of Planning and Reporting, Program Evaluation and Methodology Division, Before the Subcommittee on Science, Research, and Technology, Committee on Science, Space, and Technology, House of Representatives, GAO/T-PEMD-90-4, May 3, 1990.

[174] General Accounting Office, *Diffusing Innovations: Implementing the Technology Transfer Act of 1986*, Report to the Chairman, Committee on Science, Space, and Technology, House of Representatives, GAO/PEMD-91-

publication by the House Science Committee.[175] GAO's findings indicated "uneven" implementation of the act across agencies, according to five measures chosen as compliance indicators.

Only 44 percent of the laboratory directors were authorized at that point to negotiate CRADAs and only half had royalty-sharing programs. The report concluded that laboratory activities had not lived up to expectations, and that there was a need for massive awareness and outreach regarding technology transfer.

GAO followed this up with some analyses of miscellaneous aspects of technology transfer such as government laboratory patent licensing activities[176] and commercialization issues related to software copyrighting,[177] Also, the 1986 act required a study of royalty-sharing after five years.[178] GAO found that royalty-sharing had not increased the laboratory scientists' interest in patenting, and subsequent GAO testimony supported higher royalties.[179]

In 1993 and 1994, GAO focused on cooperative R&D agreements (CRADAs) beginning with comparisons among agencies.[180] In its comparison, GAO criticized DOE's partnership efforts, although DOE had been implementing CRADAs for a shorter period of time than the

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23, May 1991. Also, General Accounting Office, *Diffusing Innovations: Implementing the Technology Transfer Act of 1986*, Statement of Kwai-Cheung Chan, Director of Program Evaluation in Physical Systems Area, Program Evaluation and Methodology Division, Before the Subcommittee on Technology and Competitiveness, Committee on Science, Space, and Technology, House of Representatives, GAO/T-PEMD-91-5, May 30, 1991.

[175]The implication was that GAO was not sufficiently experienced in the technology transfer area, at that point, to be able to evaluate it. See Richard Chapman, "Alternative Methods to Evaluate Technology Transfer," in *Technology Commercialization and Economic Growth: Technology Transfer Society 20th Annual Meeting Proceedings, July 16-19, 1995,* Washington, DC: 1-9.

[176]General Accounting Office, *Technology Transfer: Federal Agencies' Patent Licensing Activities*. Report to Congressional Requesters, GAO/RCED-91-80, April 1991.

[177]General Accounting Office, *Copyright Law Constraints on the Transfer of Certain Federal Computer Software With Commercial Applications*, Statement of John M. Ols, Jr., Director in the Resources, Community, and Economic Development Division, Before the Committee on Commerce, Science and Transportation, United States Senate, GAO/T-RCED-91-91, September 13, 1991.

[178]General Accounting Office, *Technology Transfer: Barriers Limit Royalty Sharing's Effectiveness,* Report to Congressional Committees, GAO/RCED-93-6, December 1992.

[179]General Accounting Office, *Technology Transfer: Improving Incentives for Technology Transfer at Federal Laboratories*, Testimony before the Subcommittee on Science, Technology and Space, Committee on Commerce, Science and Transportation, United States Senate, GAO/T-RCED-94-42, October 26, 1993.

[180]General Accounting Office, *Technology Transfer: Implementation of CRADAs at NIST, Army, and DOE*, Testimony before the Subcommittee on Energy, Committee on Science and Technology, House of Representatives, GAO/T-RCED-93-53, June 10, 1993.

other two agencies examined.[181] After focussing on improving the use of CRADAs at DOE laboratories,[182] GAO focussed on the benefits of CRADAs generally.[183] For the CRADA benefits study, GAO found that agencies and companies benefitted from their collaborations, although they did not all achieve the same level of benefits. In any case, both the laboratories and companies accomplished their objectives, since the examined CRADAs resulted in the enhancement of laboratory R&D programs and the transfer of technologies into commercial products. Some of the CRADAs demonstrated a potential for long-term improvements to the nation's economy, health, and environment.

Most recently, Congress asked GAO to evaluate approaches for measuring R&D results, such as patents counts, peer reviews, bibliometrics, and return on investment.[184] Like OSTP, GAO found that output measures are specific to the mission and management of each federal agency, and that no single indicator exists to measure research results. GAO also said profit-related indicators used by the private sector could not be applied to government work.

Commerce Department Measured on a Government-Wide Basis

DOC Bienniel Reports: The Department of Commerce is required by law to report to the President and Congress every two years on federal agency implementation of the technology transfer legislation. Per this requirement, DOC issued reports in 1989, 1993 and 1996.

While the 1989 report[185] was understandably brief, the 1993 report[186] focused on the cooperative research activities of both the 1986 Federal Technology Transfer Act and the 1989 National Competitiveness Technology Transfer Act; it also included NASA's cooperative research activities.[187] It provided process-based measures (eg., number of invention disclosures) as opposed to impact measures. For example, by 1992, there were 1,300 cooperative R&D

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[181]DOE was granted CRADA authority by the 1989 act rather than the 1986 act.

[182]General Accounting Office, *Technology Transfer: Improving the Use of Cooperative R&D Agreements at DOE's Contractor-Operated Laboratories*, Report to Congressional Requestors, GAO/RCED-94-91, April 1994.

[183]General Accounting Office, *Technology Transfers: Benefits of Cooperative R&D Agreements*, Report to the Vice Chairman, Joint Economic Committee, U.S. Congress, GAO/RCED-95-52, December 1994.

[184]General Accounting Office, *Measuring Performance: Strengths and Limitations of Research Indicators*, Report to Congressional Requesters, GAO/RCED-97-91, March 1997.

[185]Department of Commerce, *The Federal Technology Transfer Act of 1986: The First Two Years*, Report to the President and the Congress from the Secretary of Commerce, July 1989.

[186]Department of Commerce, *Technology Transfer Under the Stevenson-Wydler Technology Innovation Act: The Second Biennial Report*, Report to the President and the Congress from the Secretary of Commerce, January 1993.

[187]Carried out under authority of the 1958 Space Act.

agreements in place. Also, there was a two-fold increase in licenses from 1987 to 1991, and the number of royalty-bearing licenses increased from less than fifty percent (of total licenses) in the early 1980s to more than ninety percent.

The 1996 report was broadened to discuss not just technology transfer, but also technology funding programs such as the TRP, ATP, and SBIR programs.[188] It described the transition to the new paradigm of public-private collaboration, highlighted best practices by these programs, and offered recommendations for improving partnership effectiveness. The report contained a section discussing how success should be measured, yet provided only cursory updated statistics.

Interagency Committee Attempted Consensus-Building

In the early 1990s, the Interagency Committee on Federal Technology Transfer attempted a government-wide effort to establish agreed-upon metrics for measuring laboratory technology transfer. The Committee, chaired by the Assistant Secretary for Technology Policy at the Commerce Department, established several working groups in 1992, including a Working Group on Technology Transfer Measurement and Evaluation with members from fifteen agencies and organizations.[189] The group's goal was to develop a government-wide system for measuring technology transfer effectiveness and assessing economic impact. In 1994, the Interagency Committee issued a draft report from the working group containing an agreed-upon set of definitions and measurements and data collection framework.[190] The Department of Agriculture offered to test the framework using actual data,[191] however, the work was not finalized because the committee became inactive during much of the Clinton Administration.[192]

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[188]Department of Commerce, Office of Technology Policy, *Effective Partnering: A Report to Congress on Federal Technology Partnerships*, Richard J. Brody, Project Director, April 1996.

[189]These included: Ballistic Missile Defense Organization, Departments of the Air Force, Agriculture, Army, Commerce, Energy, Interior, Navy, Treasury and the Environmental Protection Agency, NASA, National Institutes of Health, National Science Foundation, Office of the Secretary of Defense, and National Technology Transfer Center.

[190]Interagency Committee on Federal Technology Transfer, Working Group on Technology Transfer Measurement and Evaluation, *Collective Reporting and Common Measures: Draft for Comment*, Prepared by the Oak Ridge Institute for Science and Education (ORISE) Training and Management Systems Division for the U.S. Department of Energy's Technology Utilization Office, November 1994.

[191]The U.S. Department of Agriculture had performed quite a bit of its own technology transfer evaluation through various means, including the use of independent evaluators such as Richard Chapman who conducted evaluation research with the Department of Agriculture in the late 1980s and early 1990s.

[192]Late in 1997, the committee re-convened, but it is not clear whether it will continue.

Federal Laboratory Consortium Contributed Reports

FLC Defense Conversion Report and Measures: A 1994 FLC report on defense conversion addressed the issue of how to measure success in technology transfer.[193] It broke new ground in suggesting the need to use measures of cultural change to measure progress and to motivate, noting the importance of being deliberate in choosing measures because “that which is rewarded is what motivates.” The following year, the FLC testified before the House Science Committee with the following strong statement on performance metrics:[194]

> There is no issue more critical to federal technology transfer in 1995 than determining and using measures to assess its value to all participants. Disagreement appears to exist in two dimensions: (1) What types of measures truly represent the impact of technology transfer efforts? (Not just the process, which is far easier to evaluate) and (2) Which measures are sufficiently sound that they can be used across a wide range of varying technology transfer efforts? (For example, a personnel exchange program within a government-owned, contractor-operated laboratory versus a CRADA between a government-owned, government-operated laboratory and a large industry, or providing technical assistance to a local small business versus licensing an existing patent to a large international firm). The volatility of technology also contributes to the difficulties of precisely measuring its transfer. The FLC agrees that the definition and adoption of performance metrics are of the highest priority and we are working with our member laboratories and agencies in this area.

Chapman Survey of FLC Mid-Continent Region: The FLC then commissioned a study by Chapman Research Group[195] which involved a survey of eleven laboratories in the FLC’s eight-state Mid-Continent Region. The study identified both obstacles and best practices. Best practices involve: incorporating technology transfer into the laboratory’s strategic planning; having an innovative and aggressive technology transfer officer; and having supportive top management at the laboratory. Obstacles include: lack of effective outreach and in-reach (to the laboratory scientists); and unsupportive agency headquarters personnel.

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[193]Federal Laboratory Consortium, *Technology Transfer in a Time of Transition: A Guide to Defense Conversion*, 1994.

[194]Tina McKinley, *FLC Chair, Lessons Learned in Technology Transfer: 20 Years of Federal Laboratory Consortium for Technology Transfer (FLC) Experience*, Prepared for the Committee on Science, Subcommittee on Technology and Subcommittee on Basic Research, U.S. House of Representatives, June 27, 1995.

[195]Chapman Research Group, Inc., *Managing the Successful Transfer of Technology from Federal Facilities: A Survey of Selected Laboratories and Facilities in the Mid-Continent Region of the Federal Laboratory Consortium*, Federal Laboratory Consortium, 1997.

Outside Studies Compared or Combined Government, University Transfer

Bozeman NCRDP Studies: Barry Bozeman of Georgia Tech received NSF, DOE, and other funding since 1984 to develop a database for his National Comparative Research and Development Project (NCRDP). This ongoing project determined the performance and sources of influence in the U.S. R&D laboratory system, the extent of technology transfer activity, and the degrees of success. It also provided comparative data on the technical enterprises in other industrial nations. The NCRDP developed in several phases, depending upon funding. The NCRDP master database was primarily based upon questionnaires mailed to laboratory directors. Several effectiveness measures were employed, including subjective self-ratings and more objective measures. The early Bozeman work was based upon an input-output approach, where the outputs were the immediate or intermediate products of the technology transfer but, in later studies, more emphasis was placed upon ultimate impact. The findings were described in various articles highlighted below.

A 1988 Bozeman-edited symposium on evaluating technology transfer for the journal *Evaluation and Program Planning* presented Bozeman's early ideas on how technology transfer evaluation differed from evaluation of other policies.[196] In that series, he co-authored an article presenting a contingency framework for assessing technology transfer activities at U.S. national laboratories.[197] The model focused on: the technology transfer characteristics of the transferring agent, attributes of the transferred products, the transfer mechanisms, and attributes of the user. The article used Brookhaven National Laboratory as a case example.[198] Bozeman's colleague Michael Crow wrote another article in this journal series reporting on 32 laboratory case studies.[199]

Bozeman and Crow - Phase II: A 1988 article in *Public Administration Review*[200] by Bozeman and Crow (et al) built upon the earlier NCRDP work and presented results of 1987 data developed in Phase II of the project. This phase involved a survey and interviews with almost 1,000 government and university laboratories comparing technology transfer in both settings. The study showed that 52 percent of governmental laboratories and 38 percent of university

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[196]Barry Bozeman, "Editor's Introduction: Evaluating Technology Transfer and Diffusion," *Evaluation and Program Planning* 11: 63, 1988.

[197]Barry Bozeman and Maureen Fellows, "Technology Transfer at the U.S. National Laboratories: A Framework for Evaluation," *Evaluation and Program Planning* 11: 65-75, 1988.

[198]At the time, Bozeman was at Syracuse University, also located in New York.

[199]Michael Crow, "Technology and Knowledge Transfer in Energy R&D Laboratories: An Analysis of Effectiveness," *Evaluation and Program Planning* 11:76, 1988.

[200]Dianne Rahm, Barry Bozeman, and Michael Crow, "Domestic Technology Transfer and Competitiveness: An Empirical Assessment of Roles of University and Governmental R&D Laboratories," *Public Administration Review* (November/December): 969-978, 1988.

laboratories indicated they considered technology transfer to industry to be a major mission of their laboratories.

A 1990 Bozeman/Crow *Policy Sciences* article again examined technology transfer according to government, university, and industry sectors, looking specifically at the amount of bureaucratization, cooperative research, and output for each sector.[201] Their sector-based classification explained the amount of "red tape," but politics and market-based influences better explained the amount of cooperative research and output. A 1991 article examined the question of red tape in more detail.[202] Data from surveys of 276 federal and state laboratory directors showed that laboratories involved in technology transfer did not have higher levels of red tape.

Bozeman and Coker - Phase III: For Phase III of the project, in 1990, the Bozeman team mailed questionnaires to more than 1,100 laboratory directors; 47 percent were returned. A 1992 article by Bozeman and Karen Coker[203] assessed laboratory technology transfer success, taking into account laboratory receptiveness to market influences. They considered three criteria: two based upon self-evaluations, and a third based upon the number of licenses issued. The results showed that multi-mission laboratories were more successful, especially if they had low levels of bureaucratization and either ties to industry or a commercial orientation in project selection.

A 1994 article by Bozeman in the *Policy Studies Journal*[204] reported on the government subsample of the Phase III data which involved 189 laboratories or about half of the larger government laboratories. A comparison of this data with Phase II 1987 data showed that government laboratory technology transfer activity increased by more than forty percent, representing what he called "considerably enhanced activity in a relatively brief amount of time."

A 1995 report to NSF by Bozeman, Coker, and Maria Papadakis,[205] presented findings from surveys of companies interacting with government laboratories during the previous five

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[201]Barry Bozeman and Michael M. Crow, "The Environments of U.S. R&D Laboratories: Political and Market Influences," *Policy Sciences* 23: 25-56, 1990.

[202]Barry Bozeman and Michael M. Crow, "Red Tape and Technology Transfer in the U.S. Government Laboratories," *Journal of Technology Transfer* 16 (2/Spring): 29-37, 1991.

[203]Barry Bozeman and Karen Coker, "Assessing the Effectiveness of Technology Transfer from U.S. Government R&D Laboratories: The Impact of Market Orientation," *Technovation* 12 (4/ May): 239-256, 1992.

[204]Barry Bozeman, "Evaluating Government Technology Transfer: Early Impacts of the 'Cooperative Technology Paradigm'," *Policy Studies Journal* 22 (2/ Summer): 322-337, 1994.

[205]Barry Bozeman, Maria Papadakis and Karen Coker, *Industry Perspectives on Commercial Interactions with Federal Laboratories: Does the Cooperative Technology Paradigm Really Work?* Report to the National Science Foundation, Research on Science and Technology Program, Atlanta: Georgia Tech, Contract no. 9220125, January 1995.

years. The data included 229 collaborative projects (e.g., CRADA, technical assistance, license, personnel exchange), 219 firms, and 27 laboratories. The study focused on industries' assessment of the benefits of working with federal laboratories, including monetary estimates of interactions and outputs. In addition to the cost-benefit of the interactions, the study examined: who initiated the interactions, how well the companies' objectives were achieved, barriers to working with the laboratories, and extent of commercialization of the output. The results indicated that 89 percent of the companies felt the collaborative projects were a good use of their company's resources. On average, the project benefits exceeded costs by 3-to-1. The average net benefit was more than $1 million, although nearly one-third reported net costs exceeded net benefits. The projects' job creation value was modest; the average number of jobs created was 1.5, and 90 percent of the projects created no net jobs. Overall, the projects exhibited a high commercialization rate; 22 percent of the interactions led to products on the market and 38 percent had products under development.

With his extensive background in technology transfer program evaluation, a pair of "before and after" articles by Bozeman serves to highlight the frustrations in this area. Fifteen years ago, in a confident piece in the "Public Management Forum" section of *Public Administration Review*,[206] Bozeman and Jane Massey presented some guidelines for investing in policy evaluation. They encouraged evaluating policies ". . .where the direction of causality is more apparent . . .where direct effects are considered more significant than 'spillover' effects . . .where short-run benefits are claimed (avoiding premature evaluation) . . . and where the determinates of effectiveness can be controlled . . ." After fifteen years of technology transfer evaluation, Bozeman wrote another article[207] indicating that "many puzzles remain . . .There are more than enough methodological and practical challenges to keep us busy for some time." In this article, he asked questions such as, "What is a good batting average?" and "Can technology transfer be justified?"

Papadakis Evaluation: In 1995,[208] Papadakis carried her work with Bozeman further, reviewing the NCRDP data and combining it with GAO and NSF data.[209] Her findings indicated that, because technologies are most likely to emerge from the mission-oriented laboratories, they are "the least likely to spin off and diffuse throughout the industrial base." Once the DOD, DOE, and NASA hardware needs are excluded, "most of the system's R&D output is fundamental

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[206]Barry Bozeman and Jane Massey, "Investing in Policy Evaluation: Some Guidelines for Skeptical Public Managers," *Public Administration Review* (May/June): 264-270, 1982.

[207]Barry Bozeman, "What We Don't Know About Evaluating Technology Transfer: Some Puzzles Seeking Solutions," *Technology Transfer Metrics Summit Proceedings*, Sally A. Rood, editor, Chicago, Illinois: Technology Transfer Society, 46-53, June 1997.

[208]Maria Papadakis, "Federal Laboratory Missions, Products, and Competitiveness," *Journal of Technology Transfer* (April): 54-66, 1995.

[209]GAO reports were described earlier; NSF, for many years, has produced annual compilations of national scientific and engineering indicators, including federal R&D statistics.

knowledge, which flows through public domain literature and requires substantial additional processing to become commercial products." She concluded: (1) there is no reason to believe the current laboratory system can enhance competitiveness; (2) to enhance competitiveness, government laboratories must have explicit missions to do this; and (3) policy expectations (of commercial impacts) are inconsistent with policy requirements that laboratories conduct basic and applied research.

Roessner and Bean Surveys - Phase I: Beginning in the late 1980s, David Roessner at Georgia Tech and Al Bean at Lehigh University worked with the Industrial Research Institute (IRI), whose corporate members conduct about 85 percent of the industrial research in the U.S., to survey corporate opinions of working with government and university laboratories. The National Science Foundation (NSF) funded their initial 1988 survey. Roessner and Bean published the results in 1990 and 1991 articles.[210] They found that firms had a surprisingly high level of awareness of and interaction with federal laboratories, and many of them planned to increase their external R&D funding (such as for cooperative work). Roessner and Bean stated that they believed the firms including such external resources in their strategic planning would achieve stronger competitive positions than those that did not.

Roessner and Bean - Phase II: A 1992-1993 update survey by Roessner and Bean focused more specifically on industry interactions with the DOE national laboratories.[211] Both NSF and DOE funded this phase of their study which reported on the findings from 55 IRI member companies. They found that companies felt there was technology with commercial potential in the laboratories. However, since 1988, federal laboratories continued to "lag considerably behind" universities and other companies in being a source of external technology for industry. The survey also addressed questions related to problems and payoffs from companies interacting with laboratories. They found that companies interacted with government laboratories for long-term, less tangible payoffs rather than for commercialization opportunities. This caused Roessner and Bean to be concerned about the amount of trouble and expense needed in order for the government to make the connection with industry (eg., conducting seminars or incentives for scientists to make industry contacts). They also felt companies and laboratories should work to provide evidence of less tangible (but potentially higher-value) payoffs than profits.

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[210]J. David Roessner and Alden S. Bean, "Federal Technology Transfer: Industry Interactions With Federal Laboratories," *Journal of Technology Transfer* (Fall): 5-14, 1990. See also, J. David Roessner and Alden S. Bean, "How Industry Interacts with Federal Laboratories," *Research-Technology Management* 34 (4/July-August): 22-25, 1991.

[211]J. David Roessner and Anne Wise, *Patterns of Industry Interaction with Federal Laboratories: Final Report*, Georgia Institute of Technology, School of Public Policy, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, and U.S. Department of Energy Contract #19X-SK495C, May 1993. See also, J. D. Roessner and A. S. Bean, "Industry Interaction with Federal Labs Pays Off," *Research Technology Management* 36 (5): 38-40, 1993; J. David Roessner and Alden S. Bean, "Patterns of Industry Interaction with Federal Laboratories," *Journal of Technology Transfer* (December): 59 - 77, 1994.

Geisler Success Factors Survey: In terms of examining technology transfer process, in 1995, the National Science Foundation sponsored Eliezer Geisler's study of why federal laboratories succeed or fail at technology commercialization.[212] It involved 43 federal laboratories and their technology transfer offices, 51 industrial companies, and 428 scientists and engineers. The findings showed that in successful laboratories: (1) management supports cooperation with industry through incentives and the scientific personnel exhibit intrapreneurial attitudes; and (2) the cooperating companies support commercialization and their technical personnel perceive their laboratory counterparts as risk takers. Geisler also found that the incentives most likely to work are those creating a supportive environment for intrapreneurs (versus only financial incentives). Further, the reason industry and laboratories cooperate (e.g., access to technical resources) are different from the behavioral factors for successful commercialization.

Colorado Institute Survey of Best Practices: In 1993, the Department of Commerce and the Colorado Advanced Technology Institute sponsored the Colorado Institute for Technology Transfer and Implementation[213] to survey best practices in federal laboratories, universities, private companies, and technology brokers. The survey of sixty practitioners[214] produced vignettes describing 144 technology transfer best practices grouped into six core areas: strategy/ policy, communication/ organization, inventory, market assessment, resources, and reward/ recognition. The final report highlighted findings related to: core practices, role and scope of intermediaries, universities and risk, the federal bureaucracy, public and private sector commitment, management of technology transfer, understanding the market versus understanding the technology, communication and data management, changing perceptions, and student resources.

University Models for Technology Transfer Evaluation

Two series of university technology transfer studies[215] that have been used as models of how government laboratories might go about developing metrics as a group. These studies were conducted by the Association of University Technology Managers (AUTM) and the Southern Technology Council. AUTM has examined licensing royalties and other measures annually since 1991. In 1996, AUTM compiled a five-year summary of its survey covering 1991 to 1995.[216]

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[212]Eliezer Geisler, *Why Federal Laboratories Succeed or Fail at Technology Commercialization,* Report to the National Science Foundation, 1995.

[213]Lawrence K. Anderson and Brian D. Gurney, *Benchmarking Best Practices in Technology Transfer: Final Report*, Colorado Institute for Technology Transfer and Implementation, Colorado Springs, Colorado, Sponsored by Colorado Advanced Technology Institute and U.S. Department of Commerce, December 1993.

[214]A literature search identified the best practitioners.

[215]The 1980 Bayh-Dole Act encourages university technology transfer.

[216]*AUTM Licensing Survey: FY 1991 - FY 1995, Five-Year Survey Summary*, Association of University Technology Managers (AUTM), Inc., Daniel E. Massing, editor and Chair, AUTM Survey, Statistics and Metrics

The findings showed continued growth in the numbers of inventions reported, patent applications filed, patents granted, licenses executed, and royalty income generated. Also, in 1994, AUTM provided qualitative data in a one-time "public benefits" survey forwarded to respondents of the licensing survey that year.[217] The report described products patented, licensed, and on the market as a result of university technology transfer, and summarized the number of "university-founded"[218] start-up companies since 1980. The Southern Technology Council (STC) has produced a series of benchmarking reports on university technology transfer in the southeastern region of the country since the early 1990s.[219]

The AUTM Economic Impact Special Interest Group has been compiling a bibliography of economic impact studies by individual universities, and identified 44 studies by 1997. These individual university methodologies are also applicable to government laboratory technology transfer evaluation. For example, the Massachusetts Institute of Technology (MIT) Licensing Office developed a model for measuring pre-production investment by companies licensing technologies from MIT, and then extrapolated to all university licenses based upon the AUTM data.[220] This study found the nationwide investment in university-based technology was estimated to be $2 to 5 billion a year. BankBoston surveyed entrepreneurial activity by MIT alumni, and found that MIT graduates created 4,000 companies, generating 1.1 million jobs worldwide and $232 billion in annual sales.[221] This type of study could also be applicable to government laboratories since more laboratories are beginning to institute entrepreneural leave.

Another area where government laboratories could learn from university technology transfer is in regard to partnerships with consortia of companies. Evaluation of such partnerships

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Committee, 1996. AUTM changed the survey categories for the 1996 survey so the 1997 report on the 1996 survey was not cumulative. See *AUTM Licensing Survey: FY 1996 Survey Summary*, Daniel E. Massing, editor, Association of University Technology Managers, Inc., 1997.

[217]*AUTM Public Benefits Survey Summary of Results*, Prepared for Association of University Technology Managers (AUTM), Inc., Cranbury, New Jersey: Diane C. Hoffman, Inc., April 1994.

[218]Companies for which initiation was dependent upon the licensing of university technology.

[219]Louis G. Tornatzky, Paul G. Waugaman and Joel S. Bauman, *Benchmarking University-Industry Technology Transfer in the South: 1995-1996 Data*, Research Triangle Park, North Carolina: Southern Technology Council, Southern Growth Policies Board, July 1997; Louis G. Tornatzky, Paul G. Waugaman and Lucinda Casson, *Benchmarking Best Practices for University-Industry Technology Transfer: Working with Start-Up Companies*, A Report of the Southern Technology Council, Southern Growth Policies Board, Research Triangle Park, North Carolina: Southern Technology Council, October 20, 1995; Louis G. Tornatzky and Joel S. Bauman, *Outlaws or Heroes? Issues of Faculty Rewards, Organizational Culture, and University-Industry Technology Transfer*, A Benchmarking Report of the Southern Technology Council, Southern Growth Policies Board, July 1997.

[220]Lori D. Pressman et al, "Pre-Production Investment and Jobs Induced by Massachusetts Institute of Technology Exclusive Patent Licenses: A Preliminary Model to Measure the Economic Impact of University Licensing," *Journal of the Association of University Technology Managers* 7: 49-81, 1995.

[221]BankBoston, Economics Department, *MIT: The Impact of Innovation*, 1997.

would be comparable to efforts by the National Science Foundation to evaluate its Industry-University Cooperative Research Centers (IUCRC) program and Engineering Research Centers (ERC) program both of which involve industry-university partnerships.[222]

Michael Odza, editor of *Technology Access Report*, has questioned why government laboratories can't produce at least minimum technology transfer measures (eg., number of licenses and royalty amounts) across the board, as universities have.[223] By comparing university technology investments and resulting royalties with government laboratory investments, he roughly projected that government laboratories should be bringing in at least 700 new licenses each year.

A set of articles by Robert Carr compared federal laboratory and university technology transfer and analyzed best practices in government laboratory technology transfer. In the first article, Carr compared the AUTM data (on university licensing) with GAO data (on government laboratory licensing), showing that government laboratories lag certain universities in this area.[224] For example, MIT's royalty income from licensing activities in one year was over twice that of the entire DOE laboratory system the same year. He concluded that the explanation for the difference between the two sectors is due to the way each sector markets opportunities.

In the second of Carr's two-part series, he described best practices in technology transfer based upon a literature search and interviews with technology transfer professionals in both federal laboratories and universities.[225] The best practices addressed the following functions: organizing the technology transfer function, involving the science and technology staffs,

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[222]NSF contracted Denis Gray to coordinate multi-year IUCRC evaluations and develop an evaluation handbook; see National Science Foundation, *Evaluator's Handbook: NSF Industry-University Cooperative Research Centers Program*, Raleigh, NC: I/UCRC Evaluation Project, 1997. NSF contracted with Irwin Feller and David Roessner to evaluate the ERCs; see Irwin Feller and David Roessner, "What Does Industry Expect from University Partnerships?" *Issues in Science and Technology* (Fall): 80-84, 1995. The National Academy of Sciences' Government-Industry-University Roundtable developed case studies of partnerships as background for a recent workshop on their measurement; see Industrial Research Institute, Government-University-Industry Research Roundtable, and Council on Competitiveness, *Industry-University Research Collaborations: Report of a Workshop, November 28-30, 1995, Duke University*, Washington, D.C.: National Academy Press, 1996. Also, Albert Rubenstein and Eliezer Geisler have analyzed industry-university cooperation for many years; see, for example, Albert H. Rubenstein and Eliezer Geisler, "The Use of Indicators and Measures of the R&D Process in Evaluating Science and Technology Programs," *Government Innovation Policy: Design, Evaluation, Implementation,* J. David Roessner, editor, St. Martin's Press: 185-204, 1989.

[223]Michael Odza, "What the AUTM Licensing Survey Statistics Mean for Federal Labs," *Technology Transfer Metrics Summit Proceedings*, Sally A. Rood, editor, Chicago, Illinois: Technology Transfer Society, 231-235, June 1997.

[224]Robert K. Carr, "Doing Technology Transfer in Federal Laboratories" (Part 1), *Journal of Technology Transfer* 17 (2/3, Spring/Summer): 8-23, 1992.

[225]Robert K. Carr, "Menu of Best Practices in Technology Transfer" (Part 2), *Journal of Technology Transfer* 17 (2/3, Spring/Summer): 24-33, 1992.

capturing intellectual property, evaluating and patenting intellectual property, marketing technologies, preparing technologies for commercialization, transferring technology locally, using technology transfer intermediaries, and using technology search programs. The piece ended with a collection of conventional wisdom about technology transfer.

A subsequent Carr article noted that most studies have not measured the economic impact of technology transfer (as opposed to intermediate or process measures) because "measuring the economic value of technology transfer requires measuring the economic value of knowledge, an old problem."[226] He proposed development of case studies and surveys to determine the proper indicators to use, so that full-scale government-wide data collection could be based upon these refined variables.

Evaluation of Laboratory Incubators and Economic Development Projects

Government laboratories are beginning to adopt the concepts of economic development and incubators into their technology transfer and outreach programs.[227] For example, the federal facilities in Huntsville, Alabama (NASA Marshall field center and the Army Space and Strategic Command) are jointly implementing a technology transfer project through the local chamber of commerce which nearby university researchers recently evaluated.[228]

Not all incubators are necessarily high-tech oriented, although the ones associated with university campuses tend in this direction more than others.[229] Incubator evaluation work dates back to a classic 1987 study.[230] More recently, the National Business Incubation Association (NBIA) and the Southern Technology Council, along with other partners, identified best practices and surveyed 49 incubation programs and 126 incubator companies on results between 1990 and 1996.[231] The average company's sales increased by over 400 percent during its incubator stay,

[226] Robert K. Carr, "Measurement and Evaluation of Federal Technology Transfer," *Technology Commercialization and Economic Growth: Technology Transfer Society 20th Annual Meeting Proceedings, July 16-19, 1995, Washington, D.C.*: 221-230, 1995.

[227] Ann Markesen and Michael Oden, "National Laboratories as Business Incubators and Region Builders," *Journal of Technology Transfer* 21 (1-2/Spring/Summer): 93-108, 1996.

[228] Bernard J. Schroer, Phillip A. Farrington, Sherri L. Messimer and J. Ronald Thornton, "Measuring Technology Transfer Performance: A Case Study," *Journal of Technology Transfer* 20 (2/September): 39-47, 1995.

[229] About 25 percent of the total 800 U.S. incubators are associated with technology centers, according to the National business Incubation Association.

[230] Candace Campbell and David N. Allen, "The Small Business Incubator Industry: Micro-Level Economic Development," *Economic Development Quarterly* 1: 178-191, 1987.

[231] Louis G. Tornatzky, Yolanda Batts, Nancy E. McCrea, Marsha L. Shook and Louisa M. Quittman, *The Art and Craft of Technology Business Incubation: Best Practices, Strategies, and Tools from 50 Programs*, Southern Technology Council, National Business Incubation Association, and Institute for Local Government Administration and Rural Development, ISBN 0-927364, 1995.

and 87 percent of incubator graduates remained in business. The study also analyzed the impacts of four incubators, and found they generated $402,000 in local tax revenues while receiving $81,000 in operating funds.

Several groups have produced handbooks on how to evaluate the impact of local economic development projects and incubators,[232] and NBIA has been working to implement standardized metrics within the incubator community. NBIA partner Louis Tornatzky has developed a proposal for standardizing definitions and measures across technology transfer communities so that benchmarking can be done. [233] If implemented, it would involve laboratories, universities, manufacturing extension, and other technology transfer organizations.

Technology Transfer Metrics - Summary

Irwin Feller, noted for his evaluation of state and university technology programs, recently offered his assessment of progress in the field of evaluating technology transfer.[234] He noted that considerable advances have been made in terms of agency commitments to evaluation and the standards of evaluation design, but he warned that latent issues will surface as the field evolves to a higher level of understanding. When that happens, he said, there will be calls to become even more rigorous and disciplined.

It has been argued that government laboratories would avoid some criticism by developing standard evaluation procedures so that each laboratory is reporting on a uniform set of measures using consistent approaches. University-based technology transfer (including incubators) and manufacturing extension are examples of technology transfer communities that have successfully developed standardized quantitative and qualitative indicators (in the form of systems for identifying, documenting and disseminating best practices and cases).[235] However, since many government laboratories and programs have already developed their own evaluation approaches, recommendations for standardization have caused debate. A major issue revolves around the purpose of the results. For example, are the findings to be used for justifying or

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[232]Peter Bearse, *The Evaluation of Business Incubation Projects: Comprehensive Manual*, National Business Incubation Association, for the U.S. Economic Development Administration, ISBN 1-887183-19-1, December 31, 1993. See also, Nexus Associates, *Guide to Economic Development Program Evaluation*, Belmont, Massachusetts: Nexus Associates, Inc., 1996.

[233]See, Louis Tornatzky, "Pre-Concept Paper: Development of Recommended Standards for the Evaluation and Benchmarking of Technology Programs," *Technology Transfer Metrics Summit Proceedings*, Sally A. Rood, editor, Chicago, Illinois: Technology Transfer Society, p. 296-302, June 1997.

[234]Irwin Feller, "Technology Transfer: How Do We Know What Works, Summary Comments," *Technology Transfer Metrics Summit Proceedings*, Sally A. Rood, editor, Chicago, Illinois: Technology Transfer Society, 224-230, June 1997.

[235]This process, its underlying logic, and the criticism are all similar to what the NIST Manufacturing Extension Partnership program has experienced in the past half-decade.

improving programs? Either way, the laboratories point out that the record-keeping requirements for the company partners and the laboratories would be burdensome.

Another issue revolves around appropriate methodologies and there appear to be problems or misunderstandings over just about every method being used. As this review has shown, a common methodology in evaluating technology transfer involves an input-outcomes approach, where the technology transfer activity is the input. A problem with this approach is the difficulty in guaranteeing that outcomes are attributable to program inputs. Some studies used "multipliers" to estimate the economic impact generated by laboratory technology transfer. These types of analyses have been criticized, possibly because the results seem extravagant while the methods are not widely understood. Some have suggested that truly valid methods would necessitate the use of comparison and control groups. Yet there are not many examples of technology programs that have successfully done this. Two examples are the DOE-funded Energy-Related Inventions Program and the Michigan-based Performance Benchmarking Service.[236] Both efforts have been described as somewhat costly and time-consuming, yet worth the effort in terms of the credibility gained. Customer satisfaction ratings and peer review approaches require some systematizing and standardization to be useful tools. Benefit-cost analyses have been recommended as applicable, yet there are few examples of this being applied to technology transfer activities (other than manufacturing assistance), as opposed to R&D generally. Further, this approach is most applicable within a program area, and does not easily permit cross-comparisons.

It might help for one of the technology policy agencies, such as OSTP or the Commerce Department's Technology Administration, to support experimentation with some innovative ways to measure success. For example, the NIST MEP program has a pilot study using longitudinal Census Bureau data to compare the performance of client firms and non-assisted firms, while controlling for other factors that influence performance.[237]

OVERALL SUMMARY AND CONCLUSION - STUDY FILLS GAP

This chapter attempted to show that technology transfer policies have evolved alongside technology funding policies and programs. The studies analyzing the government laboratory missions eventually focussed on the laboratories' role in technology transfer. Thus, the technology policy literature converged with the technology transfer policy literature.

As an epilogue to this chapter, it should be noted that some of the emotional rhetoric associated with the political divisiveness on technology policy (such as "industrial policy" and

[236] Marilyn Brown et al, "Evaluating Technology Innovation Programs: The Use of Comparison Groups to Identify Impacts," *Research Policy* 24 (4): 669-684, 1995.

[237] Preliminary results indicate that program participation is related to productivity growth but not sales growth. See Ronald S. Jarmin, *Measuring the Impact of Manufacturing Extension*, Washington, D.C.: Center for Economic Studies, U.S. Bureau of the Census, August 1996, revised January 1997.

"picking winners") has subsided.[238] For example, although a Corporate Subsidy Reform Commission was proposed in 1997 to identify existing "corporate welfare," it was announced early-on that R&D partnerships would be exempt from its purvue. Even the phrase "critical technologies" has lost some of its earlier emotionally-laden connotations and both OSTP and CPC have standing committees on "critical technologies," although the status of federal programs in this area is not resolved.[239] Furthermore, the Competitiveness Policy Council and the Council on Competitiveness sponsored a project which included a series of regionally-oriented meetings, designed in part to try to overcome the political rift.[240] Within the DOE laboratory system, the latest laboratory review committee is continuing as the Laboratory Operations Panel, and has succeeded in making small incremental changes. Meanwhile, at least four Congressional bills are pending for reorganizing the DOE laboratories rather than abolishing the department. The R&D budget situation is calming down, as well; certain trade associations and professional societies are teaming together to back a bipartisan effort to recover the budget losses of the mid-1990s, and possibly even double the R&D budget over the next decade.

Regardless of the current lull, it has become apparent that the measurement and evaluation of science and technology programs is an area suffering from a general lack of experience. The measurement and evaluation of government technology transfer is similarly premature at this point. Agencies in both the Executive Branch and Congress (e.g., the General Accounting Office) have had problems producing meaningful results. For one thing, the relatively new technology development and transfer programs have not been in existence long enough to produce analyzable results. This is at a time when, due to budget pressures, all branches of government and the public are anxious to determine results.

Table B summarized some key technology program evaluations. Those relevant to government laboratories were presented in this chapter. The bibliography contains detailed references to additional related studies. This particular dissertation study is an assessment of the effect of technology transfer legislation and related policies. It evaluates outcomes and process based upon a qualitative analysis of a series of successful government cases using data collected from laboratory scientists and private partners. There have been many <u>individual</u> descriptive case studies of successful government technology transfer activity in a variety of literature sources. However, Table B made it apparent that there is a need for more <u>series</u> of case studies systematically developed using a consistent survey framework.[241]

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[238]Lewis M. Branscomb, "From Technology Politics to Technology Policy," *Issues in Science and Technology* (Spring): 41-48, 1997.

[239]The CPC "Subcouncil on Critical Technologies" and its annual reports was noted earlier.

[240]The final report will be released Spring 1998. An interim report is: Harvard University, Center for Science and International Affairs, *Investing in Innovation: Toward a Consensus Strategy for Federal Technology Policy,* Project on Technology Policy Assessment Steering Committee: Lewis Branscomb, Richard Florida, David Hart, James Keller and Darin Boville, Sponsored by the Competitiveness Policy Council, April 24, 1997.

[241]In 1989, through a FLC Southeast Region/ Martin Marietta Energy Systems, Inc. grant to Virginia Tech, the FLC sponsored development of a series of case studies about successful technology transfer. Alistair Brett, who

The next two chapters detail the data collected in the interviews for this study, presented as a series of cases. Chapter III presents the pre-legislation cases, and Chapter IV presents the post-legislation cases.

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was previously jointly affiliated with Virginia Tech (as Director of Technology Management and Transfer) and the state of Virginia's Center for Innovative Technology, compiled cases on twelve spin-off companies from eight federal laboratories. However, this series was intended for ultimate use in FLC-sponsored training on technology transfer rather than for measurement or evaluation purposes. See Alistair M. Brett, "Federal Laboratory Spin-Off Companies: Development of Case Studies for Training in Effective Domestic Technology Transfer," Virginia Polytechnic Institute and State University, August 9, 1989, unpublished.