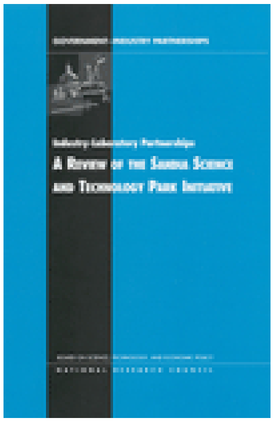

A Review of the Sandia Science and Technology Park Initiative

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

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Industry-Laboratory Partnerships

A Review of the Sandia Science and Technology Park Initiative

Charles W. Wessner, *Editor*

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The Board on Science, Technology and Economic Policy would like to express its appreciation to the participants in this symposium for generously making available their time and expertise. In particular, the Board would like to recognize Dr. Dan L. Hartley, Vice President for Laboratory Development at Sandia, for requesting this review of the Sandia S&T Park proposal. The Board would also like to recognize the key contributions of Dr. John Horrigan and John Oldfield in organizing this symposium as well as Craig Schultz and Ryan Catteau for their invaluable assistance. Lastly, the Board would like to express its appreciation to Dr. Charles Wessner for his initiative in holding this symposium, amidst several others, in order to advance our understanding of this important aspect of government-industry partnerships.

Contents

Foreword

The Sandia National Laboratories asked the Board on Science, Technology, and Economic Policy (STEP) to hold a one-day symposium to review Sandia's proposal to develop a science and technology park. In light of the importance of industry-laboratory cooperation for the STEP Board's project on *Government-Industry Partnerships for the Development of New Technologies,* the Board convened a workshop bringing together executive branch officials, congressional staff, representatives from the private sector, and regional economists to discuss the Sandia S&T park initiative. The Sandia S&T Park, which Sandia National Laboratories, the City of Albuquerque, and the State of New Mexico are jointly developing, is a 285 acre site located adjacent to Sandia National Laboratories. Groundbreaking for the park took place in May, 1999. A description of the park concept, prepared by Sandia, is included in the report in Appendix A.

Executive Summary

The end of the Cold War has created a challenging environment for the Sandia National Laboratories. Despite its more constrained budget environment, Sandia must be able to fulfill its missions amidst changing security needs in a period marked by rapid technological innovation. For example, to maintain the safety and reliability of U.S. nuclear weapons in the current test free environment requires unprecedented reliance on computer simulation, specifically through the Stockpile Stewardship Program. To meet these new challenges, the Sandia Laboratories have recognized that partnerships with the private sector are one way to ensure the laboratories' continued technological leadership.

One mechanism adopted by Sandia to promote partnerships is the development of a science and technology (S&T) park, located just outside the laboratories in Albuquerque, New Mexico. This facility is designed to encourage close cooperation with the private sector on common technological challenges. It will enable the laboratories to share costs and acquire expertise, while helping to ensure that the laboratories and their scientists stay abreast of the most recent technological innovations. As an additional benefit, a successful S&T park could also contribute to a regional environment conducive to science-based economic growth.

To explore the opportunities and challenges of an S&T park, the Sandia National Laboratories asked the National Research Council (NRC) to examine the park concept. To do so, the Board on Science, Technology, and Economic Policy (STEP) brought together executive branch officials, congressional staff, representatives from the private sector, and regional economists to review the

Sandia S&T park initiative.[1] The objective was to critically appraise the park concept, its rationale and current plans, as well as identify potential operational and policy issues.

Special attention was devoted to the following four topics:

- **Conditions of Success:** For comparative purposes two successful regional initiatives, the Research Triangle Park in North Carolina and the growth of Austin, Texas as a high-technology center, were considered. While recognizing the significant differences in institutional structure and operation between the park and these centers, speakers emphasized the importance of a clear concept, effective leadership, broad support in the community, and sustained financial commitment. They stated that these factors are likely to be more important than a fixed blueprint for developing a successful park. Several participants noted that a large research university has also typically played a role in the success of other regional development initiatives. An important cautionary note was sounded concerning the difficulty in measuring success and the corresponding difficulty in identifying a failing initiative.
- **The Importance of Partnerships:** Sandia's representatives noted that Sandia has attempted to improve its partnerships throughout the 1990s. As commercial markets continue their rapid evolution, working with the private sector is an increasingly important means for the laboratories to accomplish their missions. It also provides a means of addressing new challenges. Above all, attracting and keeping the best scientists—and maintaining their skills—requires that they be permitted to collaborate with colleagues in the private sector.
- **Institutional Design:** Energy Department Under Secretary Ernest Moniz emphasized the importance of public-private partnerships in developing new technologies for the national laboratories. At the same time, he noted that such partnerships must benefit both government and industry and that the use of the laboratories' unique resources must create public goods. In this context, foreign participation in cooperative activity can be seen as appropriate when it provides an aggregate benefit to U.S. taxpayers.

  In considering the Sandia S&T park specifically, a regional economist stressed the importance of cultivating "synergies." That is, even with first rate facilities and industrial partners, the park needs to foster an atmosphere in which knowledge flows quickly, failure is not a stigma, and

[1] The workshop on the Sandia S&T Park Initiative was carried out as part of the STEP Board's review of Government-Industry Partnerships for the Development of New Technologies, a multi-year assessment of U.S. and foreign partnerships. This report examines a key element of the U.S. innovation system, that is industry laboratory cooperation. The report does not contain formal recommendations by the Academies.

capital is available to quickly fund entrepreneurial opportunities. Sandia representatives pointed out that with the large number of Ph.D.s per capita in New Mexico, the potential for synergy with the University of New Mexico, and the city of Albuquerque's commitment to the park, significant regional support is already in place for the Sandia initiative.

- **Operational Challenges:** Discussion of this topic focused on the challenges government-industry partnerships must address, such as justifying the cost of partnerships, determining intellectual property rights, and identifying the appropriate role for public investment. Given the technology assets that Sandia brings to the park, the Sandia leadership was urged to focus its priorities on technologies and companies that bring assets complementary to those of Sandia laboratories, and therefore able to generate the maximum leverage from the park.

I

PREFACE

Preface

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

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

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

[2] For a discussion of Samuel Morse's 1837 application for a grant and the congressional

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

During the Cold War, the United States continued to emphasize technological superiority as a means of ensuring U.S. security. Government funds and costplus contracts helped to support systems and enabling technologies such as semiconductors and new materials, radar, jet engines, computer hardware and software, and missiles. For example, the government played a central role in the creation of the first electronic digital computer, the ENIAC.[5] In the post-Cold War period, the evolution of the American economy continues to be profoundly marked by government-funded research in areas

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

[3] David Mowery, "Collaborative R&D: how effective is it?" *Issues in Science and Technology*. 1998, p. 37.

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

[5] Kenneth Flamm, *Creating the Computer*. Washington, DC: The Brookings Institution, 1988, chapters 1-3.

such as microelectronics, robotics, biotechnology, the human genome, and through investments such as ARPANET, the forerunner of today's Internet.

Despite the important role the U.S. government has played in the development of the American economy, there is little consensus concerning the principle of government participation and there is often considerable debate about the appropriate mechanisms of participation. At the same time, in light of the rising costs, substantial risks and the breadth of potential applications of new technologies, some believe that a supportive policy framework by the government is necessary if new, welfare-enhancing and wealth-generating technologies are to be developed and brought to the market.

Since 1991 the National Research Council's Board on Science, Technology, and Economic Policy (STEP) has undertaken a program of activities to improve policy makers' understanding of the interconnections of science, technology, and economic policy and their importance for the American economy and its international competitive position. The Board's activities have corresponded with increased policy recognition of the importance of technology to economic growth. The new economic growth theory emphasizes the role of technology creation, which is believed to be characterized by significant growth externalities.[6] A consequence of the renewed appreciation of growth externalities is recognition of the economic geography of economic development. With growth externalities coming about in part from the exchanges of knowledge among innovators, certain regions become centers for particular types of high growth activities. Innovators are able to take advantage of knowledge that is "in the air" which addresses technology and other business development issues.[7]

In addition, some economists have suggested limitations to traditional trade theory, particularly with respect to the reality of imperfect international competition.[8] Recent economic analysis suggests that high-technology is often characterized by increasing rather than decreasing returns, justifying to some the proposition that governments can capture permanent advantage in key industries by providing relatively small, but potentially decisive support to bring national industries up the learning curve and down the cost curve. The increasing theoretical recognition of the dynamic element of technological innovation, in particular its cumulative nature, has provided

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

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

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

an intellectual underpinning for strategic trade concepts that emphasize the dynamic nature of international competition in high-technology industries.[9]

PROJECT ORIGINS

The growth in government programs to support high technology industry within national economies and their impact on international science and technology cooperation and on the multilateral trading system are of considerable interest worldwide. Accordingly, these topics were taken up by STEP in a study carried out in conjunction with the Hamburg Institute for Economic Research and the Institute for World Economics in Kiel. One of the principal recommendations for further work emerging from that study was a call for an analysis of the principles of effective cooperation in technology development, to include lessons from national and international consortia, including eligibility standards and assessments of what new cooperative mechanisms might be developed to meet the challenges of international cooperation in high-technology products.[10]

In many high-technology industries, the burgeoning development costs for new technologies, the dispersal of technological expertise, and the growing importance of regulatory and environmental issues have provided powerful incentives for public-private cooperation. Notwithstanding the unsettled policy environment in Washington, collaborative programs have expanded substantially. Under the Reagan administration, SEMATECH was established after much debate.[11] The Bush administration saw the creation of the Advanced Technology Program (ATP) in the National Institute of Standards and Technology. The Clinton administration came to office with an emphasis on civilian technology programs, substantially expanding the ATP and creating the Technology Reinvestment Program (TRP).[12] The rapid

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[9] For a discussion of governments' efforts to capture new technologies and the industries they spawn for their national economies, see National Research Council, *Conflict and Cooperation in National Competition for High-Technology Industry*, National Academy Press, Washington, D.C. 1996, pp. 28-40.

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

[11] For a review of SEMATECH, see the National Research Council, 1996, *op.cit.*, pp. 141-151. For one of the most comprehensive assessments of SEMATECH, see John B. Horrigan, "Cooperating Competitors: A Comparison of MCC and SEMATECH," monograph, National Research Council, Washington, D.C. forthcoming.

[12] For an analysis of ATP, see Christopher T. Hill, "The Advanced Technology Program: opportunities for enhancement," in Lewis Branscomb and James Keller, eds. *Investing in Innovation: Creating a Research and Innovation Policy.* Cambridge, Mass., MIT Press, 1998, pp.

expansion of these programs encountered significant opposition, rekindling the national debate on the appropriate role of the government in fostering new technologies. Indeed, broader philosophical questions about the appropriate role for government in collaborating with industry have tended to obscure the need for policy makers to draw lessons from current and previous collaborative efforts.

Given the considerable change in federal research and development budgets since the end of the Cold War, and the reduced role of many centralized laboratories in the private sector, government-industry collaboration is of growing importance, yet it has seen remarkably little objective analysis. At one level, analysis may contribute to a better appreciation of the role of collaboration between government and industry in the development of the U.S. economy. Writing twenty years ago, one well-known American economist observed that Americans are still remarkably uninformed about the long history of policies aimed at stimulating innovation.[13] Today, many Americans appreciate the contribution of technology to the current period of robust economic growth, however, there is little evidence that Americans are aware of the history of federal support for technological innovation, from radio to the Internet.

Perhaps a more compelling argument for assessment is the simple fact that government intervention in the market is fraught with risk. There are cases of major success resulting from federal support to the computer or semiconductor industries, where the Department of Defense served as a source of R&D and as a reliable, early buyer of products.[14] There are also cases of major frustration. Landmarks would include projects such as the Supersonic Transport, the Synfuels Corporation, and the Clinch River Breeder reactor.[15] Regular assessment is vital to ensure continued technical viability,

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143-173. For an excellent analysis of the TRP, see Jay Stowsky, "Politics and Policy: The Technology Reinvestment Program and the Dilemmas of Dual Use." Mimeo, University of California, 1996. See also, Linda R. Cohen, "Dual-use and the Technology Reinvestment Project." in Branscomb and Keller, *op.cit.*, pp. 174-193.

[13] Otis L. Graham, *Losing Time: The Industrial Policy Debate.* Harvard University Press, Cambridge, Mass., 1992, p. 250. Graham cites Richard Nelson's observations at the end of the Carter Administration. The situation may not have improved. Writing in 1994, James Fallows makes a similar observation (see *Looking into the Sun*: *The Rise of the New East Asian Economic and Political System.* New York: Pantheon Books, 1994, p. 196). See also Thomas McCraw's "Mercantilism and the market: antecedents of American industrial policy," in *The Politics of Industrial Policy,* Claude E. Barfield and William A. Schambra, eds., American Enterprise Institute for Public Policy Research, Washington, D.C., 1986, pp. 33-62.

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

[15]See Linda R. Cohen and Roger G. Noll, *The Technology Pork Barrel*, The Brookings Institution, Washington, D.C., 1991, pp. 97, 178, 259-320, 217-258. An interesing review of technology development programs, mainly from the 1970s, the analysis is less negative than the title suggests. The volume identifies some successful R&D projects such as the photovoltaic electricity program. The programs of the 1980s were structured differently.

though cost-sharing requirements can be an effective safeguard. Assessment can also help avoid "political capture" of projects, especially large commercial demonstration efforts.[16] Even successful collaborations face the challenge of adapting programs to rapidly changing technologies.[17] Assessment thus becomes a means of keeping programs relevant. Assessment can also have the virtue of reminding policymakers of the need for humility before the "black box" of innovation. As one observer notes, "experience argues for hedged commitments, constant reappraisal, maintenance of options, pluralism of advice and decision makers."[18]

From an international perspective, understanding the benefits and challenges of these programs is also important insofar as they have been, and remain, a central element in the national development strategies of both industrial and industrializing countries. Governments have shown a great deal of imagination in their choice of mechanisms designed to support industry. They have adopted a wide range of policies from trade regulations designed to protect domestic products from foreign competition, to tax rebates intended to stimulate the export of selected domestic products. They provide government R&D funding for enterprises of particular interest, and sometimes give overt support through direct grants, loans, and equity investments or more opaque support through mechanisms such as tax deferral.[19] Data collected by the Paris-based Organization for Economic Cooperation and Development suggest that worldwide government expenditures on support for high-technology industries involve significant resources and are increasingly focused on what policy makers consider to be strategic industries.[20]

The United States is an active, if unavowed, participant in this global competition, at both the state and the federal level. Indeed, the United States has a remarkably wide range of public-private partnerships in high-technology sectors.[21] In addition to the well-known cases mentioned above,

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

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

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

[19] National Research Council, 1996, *op.cit.*, Box B., pp. 39-40.

[20] *Ibid.*

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

there are public-private consortia of many types. They can be classified in a number of ways, such as by the economic objective of the partnership, that is, to leverage the social benefits associated with federal R&D activity, to enhance the position of a national industry, or to deploy industrial R&D to meet military or other government missions.[22] An illustrative list would include partnerships in sectors such as electronic storage, flat panel displays, turbine technologies, new textile manufacturing techniques, new materials, magnetic storage, next-generation vehicles, batteries, biotechnology, optoelectronics, and ship construction. The list would also include programs such as the national manufacturing initiative, National Science Foundation's (NSF) engineering research centers, NSF's science and technology centers, the National Institute of Science and Technology's Manufacturing Extension Program, and the multi-agency Small Business Innovation Research Program, among others. University-industry cooperation is also on the upswing, with a significant percentage of university R&D now provided by industry and through innovative cooperation efforts such as Semiconductor Industry Association's MARCO program. In addition, there are extensive cooperative agreements with the national laboratories. The proliferation of these programs provides a rich base of experience for assessment.

PROJECT STEERING COMMITTEE

The expansion of cooperative activities highlights the need for better understanding of the opportunities and limitations of these programs and the conditions most likely to ensure success. Reflecting the interest of policy makers in this topic, the STEP Board initiated the project on "Government-Industry Partnerships for the Development of New Technologies," which has benefited from broad support among federal agencies. These include the U.S. Department of Defense, the U.S. Department of Energy, the National Science Foundation, the National Institutes of Health, the National Aeronautics and Space Administration, the National Institute of Standards and Technology, as well as a diverse group of private corporations. To carry out this analysis, the STEP Board has assembled a distinguished multidisciplinary steering committee for government-industry partnerships, listed in the front of this report. The committee's principal tasks are to provide overall direc-

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

tion and relevant expertise in the assessment of the issues raised by the project. At the conclusion of the project, the steering committee will develop a consensus report outlining their findings and recommendations on the issues reviewed by the project.

As a basis for the consensus report, the steering committee has undertaken to commission research and convene a series of fact-finding meetings in the form of workshops, symposia, and conferences as a means of informing its deliberations. This symposium represents one element of this fact finding effort. It is the second in a series of fact-finding meetings convened under the auspices of the STEP Board and under the direction of the steering committee.[23]

A number of distinguished individuals deserve recognition for their willingness to review this report. These individuals were chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review process: Harold Agnew, University of California; David Bruce Audretsch, Indiana University; Albert N. Link, UNC Greensboro; Michael L. Luger, UNC-Chapel Hill; Jurgen Schmandt, University of Texas, Austin; Richard M. Thayer, TTI Inc.; and especially the report coordinator, Alexander H. Flax. Although these individuals have provided constructive comments and suggestions, it must be emphasized that responsibility for the final content of this report rests entirely with the STEP Board and the NRC.

Given the quality and number of presentations at this second symposium, summarizing the proceedings was a challenge. Every effort was made to capture the main points made during presentations and ensuing discussions, within the constraints imposed by the nature of a symposium summary. We apologize in advance for inadvertent errors and omissions in the summary. We also take this opportunity to thank our speakers and participants for

[23] The first meeting of this series resulted in the National Research Council report *The SBIR Program: Challenges and Opportunities*. National Academy Press, Washington, D.C., 1999. Other reports include *The SBIR Program: An Assessment of DoD's Fast Track Initiative.* National Academy Press, Washington, D.C., 1999 and *The Advanced Technology Program: Challenges and Opportunities.* National Academy Press, Washington, D.C., 1999. With respect to the international dimension of the project, see *New Vistas in Transatlantic Science and Technology Cooperation.* National Academy Press, Washington, D.C., 1999.

making their experience and expertise available to Sandia and our project. Finally, we emphasize that the proceedings that follow do not make findings or recommendations; rather, they seek to capture the different perspectives of the participants on the Sandia proposal for a science and technology park.

Charles W. Wessner

II

INTRODUCTION

Introduction

Defense expenditure has been a leading contributor to technological advance and regional growth in the United States from Eli Whitney's first contract in 1798 for muskets with interchangeable parts to the first operational teraflop computer.[24] Indeed, the technological landscape of the United States has been shaped in no small part by the requirements of national security and other national commitments.[25] Similarly, universities have been a key source of regional economic growth in the United States, from the Civil War passage of the Morrill Act to Stanford and MIT startups.[26]

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[24] For an informative discussion of the impact of military expenditure on the growth of the American economy, see Geoffrey Perret, *A Country Made By War: From the Revolution to Vietnam—The Story of America's Rise to Power*. Random House, New York, 1989. For the conditions surrounding the award of the contract to Whitney, see pp. 94-97. The teraflop computer was developed under a collaborative program by Intel, Sandia, and the U.S. Department of Energy. The teraflop is able to complete one trillion calculations per second, one thousand times faster than computers of a decade ago. The teraflops computer's memory capacity is also one thousand times greater than supercomputers of the 1980s. "Sandia and a Revolution in Engineering: A Fact Sheet," Sandia National Laboratories, Albuquerque, N.M., 1997. Available on the worldwide web at: http://www.sandia.gov/RIE/SandiaRIE.htm.

[25] For an overview of the U.S. innovation system and that of 15 other countries, see Richard Nelson, *National Innovation Systems: A Comparative Analysis.* Oxford University Press, New York, 1993.

[26] See, for example *MIT: The Impact of Innovation,* BankBoston Economics Department, Boston, Mass., 1997. While the report may overstate the role of MIT alone, the analysis nonetheless highlights the contribution of major universities, such as Stanford and MIT, in the development of clusters of technological innovation and economic growth. On the importance of clusters, See Michael Porter, *The Competitive Advantage of Nations.* Free Press, New York, 1990.

The prominent role of defense expenditure and the American universities in the U.S. innovation system is undergoing a period of considerable change.[27] With the increasing pressure on defense and university budgets presenting new challenges to traditional roles, the post-Cold War pressure on research and development (R&D) in the public sector and the realignment of R&D programs in the private sector have tightened R&D budgets and contributed to the expansion of collaborative research and development activities.[28]

Another element in this changing post-Cold War environment is the debate about the realignment of the missions of the U.S. national laboratories. However, despite the immense changes brought about by the end of the cold war, the traditional mission of Sandia National Laboratories remains paramount. At least for the foreseeable future, the national laboratories will retain major responsibilities for the nation's nuclear weapons stockpile. This task is infinitely more complex in the current test-free environment. To fulfill this unparalleled responsibility, the federal government has made and continues to make substantial investments in the laboratories, which have developed a tremendous store of technology and talent. In their role as a steward of the nation's nuclear weapons programs, the Sandia National Laboratores currently expend approximately $1.3 billion annually and employ over 7,000 people. Laboratories such as Sandia are seen as having unique capabilities, facilities, and equipment, such as the teraflops computer. In many cases, these government assets cannot be duplicated at a reasonable cost, or at all, by private firms. The laboratories are consequently seen as a unique national resource.

Just as the laboratories offer much to the private sector, the laboratories themselves recognize that they cannot fulfill their mission in isolation, especially given today's rapid pace of innovation. To remain effective, laboratories such as Sandia and others understand that they must stay abreast of the rapid technological change taking place within the commercial arena. This means building and maintaining ties to the private sector. One means of encouraging this mutually beneficial exchange is the proposal, put forward

[27] See D. Mowery and N. Rosenberg, *Paths of Innovation: Technological Change in 20th Century America,* Cambridge University Press, New York, (pp. 11-12, chapter 2).

[28] *Ibid.* Mowery and Rosenberg suggest that the U.S. R&D system has undergone profound structural change this century, first through "the rapid exploitation by U.S. firms of the 'invention of the art of invention'" pioneered in Germany and, secondly, as a result of the shifting roles of industry, government and universities as funders and performers of R&D. They suggest that the post-war R&D system with its large, well-funded research universities and federal research contracts with industry was internationally unique and is now facing a period of substantial evolution as a result of the changes since 1989 in the international political environment. See also Mowery's recent article "Collaborative R&D: how effective is it," *Issues in Science and Technology*, 1998, p. 37.

by the Sandia management, to develop a science and technology (S&T) park contiguous with the laboratory in Albuquerque, New Mexico.

The Sandia S&T park is to exist as a legally separate entity from the laboratory itself. It is perhaps best viewed as a mechanism, in conjunction with companies engaged in cooperative research and development agreements (CRADAs) with Sandia, to help the laboratory fulfill its mission while also drawing on the unique assets of the Albuquerque region. An undertaking of this scope is inherently complex, and in the case of a national laboratory such as Sandia, there are a number of significant policy issues to be addressed.[29] To ensure a complete discussion of the full range of issues relevant to this initiative, the Sandia National Laboratories asked the Board on Science, Technology, and Economic Policy (STEP) at the National Research Council to convene a symposium to discuss the Sandia plan for a S&T park.

The STEP Board responded positively to this request in part because Sandia's role in Albuquerque and the S&T park raise a number of policy issues of direct interest to the STEP Board's current review of U.S. government-industry partnerships.[30] Foremost among these questions is how best to manage government-industry partnerships to provide for effective exploitation of commercially relevant research, while taking into account the interests of taxpayers and broader U.S. national interests. This includes developing procedures to manage—and balance—the conditions of access by domestic and foreign corporations to technologies and activities that are at least indirectly supported by the U.S. taxpayer. Similarly, developing reasonable and accurate metrics to assess success and failure in a complex, long-term undertaking such as a S&T park is of major interest to the Sandia management. Last, the Sandia S&T parks initiative is one element of Sandia's interaction with the U.S. economy ranging from its extensive supplier networks to its existing partnerships with industry. All of these activities, and the assessment challenges they entail, are of great interest to the Government-Industry Partnerships project as a whole.

To consider these and other issues, the STEP Board brought together

[29] As David Mowery observed recently, "Managing R &D collaboration between industrial firms and universities or federal laboratories is difficult, and problems of implementation and management frequently hamper the realization of other goals such as collaboration. Collaborative R&D may accelerate the transfer of research results from these public R&D performers to industry, but the devil is in the details. The sheer complexity of the management requirements for R&D collaborations, especially those involving many firms and more than one university or laboratory, may slow technology transfer." "Collaborative R&D: how effective is it," *op. cit.,* p. 40. For a comprehensive view of the "alternative futures," for the Department of Energy National Laboratories, see the "Galvin Report," *Alternative Futures for the Department of Energy National Laboratories,* U.S. Department of Energy, Washington, D.C., 1995.

[30] The origins and goals of the project are described in the Preface to this report.

top members of the Sandia management, expert regional economists, senior representatives from the private sector, key congressional staff, and leading officials from executive branch agencies. (A full list of participants is included in Appendix B). We were particularly pleased to have Robert Simon from the office of Senator Jeff Bingaman join us to introduce the topic and place the S&T park initiative in the context of broader U.S. S&T policy. While reminding us of the national desire of local authorities to see their localities become poles of self-sustaining growth, Simon also emphasized the key importance of innovation in the growth of the American economy.

The symposium itself was divided into four main sessions. The first panel, led by Henry Kelly of the White House Office of Science and Technology Policy, presented an overview of recent experience from North Carolina's Research Triangle Park and the experience of the University of Texas and Austin itself. Dr. Kelly outlined a number of new national needs where the exceptional resources of the national laboratories may be able to make significant contributions, either to U.S. security or to broader national welfare. These could include collaborative research on topics as diverse and important as emerging environmental and health issues, public safety, and enabling information technologies.

The next two speakers reviewed the experiences of several S&T parks generally considered to be successful, the Research Triangle Park in North Carolina and two initiatives in Texas, Austin's evolution as a high-technology center and the Houston Area Research Center. Both speakers emphasized the importance of a clear vision, effective leadership, broad-based support, and a sustained financial commitment. In focusing on the well known Texas and North Carolina cases, it was thought that their success would serve as useful models for the Sandia initiative.[31] Notwithstanding the success of the parks described by Michael Luger and Jurgen Schmandt, Irwin Feller posed a number of challenging questions concerning the role of federal funds, opportunity costs, and the difficulty of measuring success in an enterprise with the long time horizons characteristic of a S&T park.

The second panel, moderated by Thomas Mays, recently of the National Cancer Institute, addressed the key issue of technology transfer from the national laboratories to the private sector and the increasing need for the laboratories to have ready access to innovations generated through rapidly changing commercial technologies. In this session, Albert Narath of Lockheed

[31] It is important to note that the term "S&T park" is used expansively here, and that such initiatives can take a number of different forms. Some initiatives may be rather directly tied to universities—often located on university grounds or nearby. Others may be distinct "incubators," that is, facilities that provide support services (e.g., shared office, accounting, laboratory space), which are located in business-park or campus-like settings. The Sandia park's relationship with a national laboratory is distinctive, but by no means unique.

Martin, which operates Sandia National Laboratories, outlined the rationale for the park, and Sandia's Dan Hartley summarized the current park concept. (A more complete statement of the Sandia management's vision for the park is included in Appendix A.) In his comments, Kenneth Flamm cautioned that it is important for the labs to ensure that their CRADA partners are complementary to the core missions of the laboratories. Keeping this and other caveats in mind, Dr. Flamm noted that the S&T park concept could offer an opportunity to transition the laboratories toward more industry-oriented missions. Other speakers emphasized that the prime justification for projects of this type is to facilitate technology transfer with higher social returns for the nation as a whole.

The third panel, chaired by Under Secretary for the Department of Energy Ernest Moniz, brought together leading experts in S&T parks as well as representatives of both small and large high-technology companies and organized labor. In his presentation, Dr. Moniz emphasized that the Department of Energy sees public-private partnerships as essential for the development of new technologies and for the maintenance of a high-technology supplier base for the laboratories. Dr. Moniz added that his department is in the process of developing principles for public-private partnerships. He noted, for example, that one principle would be that partnership agreements should benefit both the government and the industry. In the case of the laboratories, their unique knowledge and facilities should be the basis for successful collaboration. He also suggested that partnerships that create a public good, exploitable by many firms, should be encouraged; he added that participation by foreign firms can be appropriate to the extent that their participation provides aggregate benefit to U.S. taxpayers.

Dr. Moniz also drew attention to a paradox of public-private partnerships. Partnerships pose risks for the management both in failure and in success. Failed partnerships are to be avoided because they waste federal funds. Yet worthwhile research partnerships necessarily risk failure. At the other end of the spectrum, successful partnerships can be criticized because private sector firms may profit from the success.

In addressing metrics for success, Edward Malecki suggested that there are multiple criteria to consider. These include broad categories such as economic success (e.g., attracting firms and generating jobs) and more narrowly drawn categories such as developing entrepreneurial growth and creating a sustainable milieu for innovation, as policy makers in Europe have emphasized. He also underscored the importance of sustained linkages between government, university, and industry.

The fourth session, moderated by Clark McFadden, addressed the policy challenges that must be taken into account by this type of initiative. These include issues such as funding and governance, appropriate levels and types of cost sharing and cost recovery, timely and equitable resolution of intellectual property questions, and the sometimes vexing issue of access to the laboratory facilities by foreign firms. Although this is admittedly a broad range of issues to take up in a single symposium, the discussion captured the many operational and policy challenges faced by the Sandia management as they move forward with the S&T park initiative.

At this writing, the United States continues to enjoy sustained economic growth, even as prospects for the world economy become less certain. Whatever the immediate future holds, the pressures of global competition will continue to create new challenges for the United States to nurture and sustain growth in regions with quite different economic assets. The laboratories will remain a key element of the U.S. defense infrastructure, and, as such, must deploy the best technologies available. Linking the technological know-how of national laboratories to the commercial sector through a science and technology park represents an innovative approach to meeting these challenges. We hope this summary of the Sandia S&T park proposal contributes to a fuller appreciation of the policy issues raised by this initiative and to a better understanding of the assets and opportunities that the Sandia National Laboratories offer for the Albuquerque region and the nation.

Charles W. Wessner

III

PROCEEDINGS

Welcome

Charles W. Wessner
National Research Council

On behalf of the National Research Council, Dr. Wessner welcomed the participants to the National Academy of Sciences for this "Symposium on Industry-Laboratory Partnerships: The Role of S&T Parks." He noted that this event is one of a series of fact-finding meetings of the Science, Technology, and Economic Policy (STEP) Board's major project of "Government–Industry Partnerships for the Development of New Technologies," whose goal is to review different types of cooperative programs and sources of past successes and failures in government–industry cooperation. The project will also examine partnership practices abroad both as a point of comparison and to establish principles and mechanisms for sustainable international cooperation. The overall goal of the project is to develop "best-practice" principles and models for government–industry cooperation.[32] In this context, transferring technology and promoting knowledge spillovers from the laboratories to the private sector are a key issues for the project.

[32] There is considerable variety in government-industry partnership programs. The National Science Foundation and the Defense Department's Advanced Research Project Agency generally use research grants and contracts in the conduct of partnerships. CRADAs are partnerships that usually involve the participation of a government research laboratory. Even within partnership programs there can be considerable variation. In the Small Business Innovation Research Program, in which government agencies set aside R&D funds for small businesses, the Defense Department typically has research contracts with small businesses, while the National Institutes of Health often provides research grants to small business. For an overview of Federal and state partnerships, see Christopher Coburn and Dan Bergland, *Partnerships: A Compendium of State and Federal Cooperative Technology Programs*. Columbus, OH: Battelle, 1995.

In his opening remarks, Dr. Wessner identified four primary objectives for the symposium. These are to:

- examine the question of what makes regional development efforts work. This effort is of particular importance insofar as national economic development tends to occur on a regional basis, usually through the emergence of clusters of technical expertise and commercial success that support the economy as a whole.
- review Sandia's proposals for a S&T park, focusing on Sandia's motivations for developing the park, as well as on Sandia's development plans.
- consider factors that might make Sandia's effort successful, drawing on U.S. experience with S&T parks and on expertise from a wide range of representatives from industry, academia, and labor.
- assess both operational and policy challenges that might be encountered as Sandia moves forward with its plans.

Opening Remarks

Robert Simon
Office of Senator Jeff Bingaman

On behalf of Senator Bingaman, Dr. Simon thanked the National Academy of Sciences for its work to date on government-industry partnerships, applauding its emphasis on operational issues, that is, on what works and what does not in this complex and sometimes divisive area of public policy. With respect to the specific topic of discussion, Dr. Simon noted that Senator Bingaman strongly supports the Sandia S&T park proposal.

GOVERNMENT'S ROLE IN AN INNOVATION-BASED SOCIETY

Concerning the broader question at hand, Dr. Simon observed that the park proposal captures the concept of S&T policy "beyond the budget": What should the federal government do in conjunction with state and local governments to foster the emergence of more clusters such as Silicon Valley or Route 128? He wondered whether the federal labs could act as catalysts in a world where some foreign governments, such as Taiwan, clearly see an expanding role for such institutions in the commercial sphere.

Referring to a February 2, 1998, speech made by Senator Bingaman at the National Research Council's "Forum on Science and Technology and Economic Productivity," Dr. Simon observed that the critical question is whether progress is being made toward the reformulation of the United States as an innovation-based society for all of its citizens, a concept he defined as a society oriented toward the creation and distribution of new knowledge by a wide range of institutions. Understanding the national innovation system, a concept developed by Columbia University's Richard Nelson, is essential to that reformulation.[33] In that regard, Dr. Simon noted that the traditional linear model of innovation is completely inadequate for understanding the process of innovation today. In its place, he suggested that the concept of an ecosystem might be a more useful approach.

Because increasing innovation will, over the long term, be the largest single determinant of the quality of life in the United States and abroad, Dr. Simon suggested that it is very important to determine the appropriate federal role in the U.S. innovation system.

PROMOTING "STICKY REGIONS"

In Senator Bingaman's view, a key question is how the federal government should encourage local and state efforts to use S&T parks to foster what he calls "sticky regions," that is, regions where clusters of technical resources, customers, suppliers, financial and management resources, and innovation combine to create economic growth and improve the national quality of life. Clearly, this would mean working through the traditional federalist approach, with federal, state, and local governments each focusing on their own areas of competence.

Sticky regions share some important characteristics, which together encourage firms to remain within the region, Dr. Simon noted. These characteristics might include a highly skilled specialized labor force, vigorous open sources of new science and technology (e.g., research universities), networks of local venture capitalists who understand their industries, and a well-developed physical infrastructure. However, although all these ingredients are undoubtedly important, they are not sufficient to explain the growth of these regions. In addition, institutions in the area would need to be highly porous in order to create a vigorous network of horizontal links between firms, rather than vertically integrated stand-alone operations.[34]

THE POTENTIAL OF S&T PARKS

In some regions, S&T parks have already played an essential role in encouraging and facilitating this mixing between institutions, Dr. Simon remarked. In that connection, the government could play three key roles:

- bolster dynamic regions,
- manage federal resources effectively, and
- support the development of sticky regions such as Albuquerque, New Mexico.

[33] See R. R. Nelson, ed., *National Innovation Systems: A Comparative Study*, Oxford University Press, New York, 1993.

[34] For an elaboration of this view, see A. Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Harvard University Press, Cambridge, Mass., 1994.

Clearly, government efforts in this policy area will face many challenges, Dr. Simon continued. And although there are areas in northern New Mexico that have the potential to become sticky regions, it would be hard to duplicate Silicon Valley. It is, after all, much easier to identify sticky regions than to create them.

Dr. Simon observed that the federal laboratories face some specific challenges in this process that university science parks do not. New relations with industry would have to be developed, which in an increasingly global world would also include relations with foreign-owned companies and their U.S. subsidiaries. Those problems have been, and will probably continue to be, somewhat vexing.

In addition, Dr. Simon continued, the labs would have to remain closed for some purposes, in light of their nuclear defense responsibilities, even though S&T parks clearly require somewhat open relations between the tenants and the sponsoring research institution. Managing this dilemma will be an important responsibility of both the U.S. Department of Energy (DOE) and Congress. Resolving these issues will require considerable work from all participants in the process.

Sandia has made significant progress in opening its resources to U.S. industry, Dr. Simon concluded. The proposals for a S&T park are very forward-looking, and he hoped that the remainder of the symposium would identify useful ways in which the U.S. government could support its development. In closing, he emphasized that Senator Bingaman would welcome any specific suggestions that might contribute to the creation of a sticky region around Sandia.

Panel I

Science and Technology Parks: An Overview of Recent Experience

Moderator:
Henry Kelly
White House Office of Science and Technology Policy

Dr. Kelly observed that the U.S. innovation system has been highly successful in the past. However, maintaining its health represents the largest challenge of the new millennium. Three new challenges in particular seem significant:

- the end of the Cold War, which had until recently underpinned almost all megascience projects both in the U.S. Department of Defense and NASA;
- deregulation of huge economic institutions (e.g., airlines, telecommunications) in which monopolies have long supported large centralized corporate R&D labs. That hidden subsidy has vanished, and, although deregulation would support innovation in the long run, there are some shorter-term problems to overcome;
- changes in the geography of innovation, which have become more internationalized, and where technology is already changing the way in which research is being conducted. Collaborative research is now conducted across large distances in ways that were unthinkable only a few years ago.

Research partnerships could be a key tool for meeting these challenges, Dr. Kelly remarked, as the partners become better at integrating government research with industry needs. Clearly, the difficulties would be in detailed implementation and operations, and it would be very important to learn from experience.

Dr. Kelly also noted that the nature of the partnership would depend very sensitively on the nature of the research being conducted, as several different types of projects currently receive public support. These include:

- health research at the National Institutes of Health, where federal support is crucial, and where the nature of collaboration is very different from, for example, manufacturing projects;
- environmental research, where partnerships with industry are likely to be a crucial part of any solution, but where the process is likely to be different with each industry (for example, R&D in the auto industry is likely to be conducted quite differently from that in construction);
- public safety research, such as airline safety, where numerous types of research often need to be coordinated; and
- research in information technology, where efforts to develop partnerships has been somewhat less successful, partly because expertise is scattered throughout the federal government.

Dr. Kelly noted, however, that all of these research approaches create opportunities for local partnership development. He suggested that the key issues might be the logic driving sticky regions and the ways in which local communities can exploit the presence of major research institutions. From this perspective, he welcomed the symposium's review of the experience of two regions, Research Triangle Park and Austin, Texas, known for their concentration of high-technology industry and research facilities.

THE RESEARCH TRIANGLE EXPERIENCE

Michael Luger
University of North Carolina

Dr. Luger presented the results of his research on the success and failure of S&T parks in the United States and abroad.[35] He divided his research findings into four main areas:

- an overview of S&T parks,
- an examination of why some parks succeed and others fail,
- a case study of the Research Triangle Park (RTP) in North Carolina, and
- a look at the experience with S&T parks overseas.

These findings reflect both research from his book *Technology in the Garden* and subsequent research that includes both his own academic research and research undertaken at the request of S&T parks and related institutions in the United States and abroad.

[35] M. Luger and H. Goldstein, *Technology in the Garden: Research Parks and Regional Economic Development,* University of North Carolina Press, Chapel Hill, 1991.

An Overview of S&T Parks

Drawing on a series of charts (see Appendix C), Dr. Luger noted that there are more than 150 S&T parks in the United States. Some are growing, a few are stagnant or declining. Most of the growth in S&T parks took place during the late 1980s and early 1990s.

Faster-growing parks tend to have more contact with research universities, Dr. Luger continued. S&T parks established in the 1990s appear to be specializing more in sectors such as biotechnology, software, medical devices and research, advanced materials, telecommunications, semiconductors, and optics.

Defining Success

In assessing S&T parks, it is very important to define success clearly at the outset, Dr. Luger remarked. He noted that there are multiple dimensions of success, and that parks can be seen as

- real estate projects, as parks have to attract a sufficient number of companies to survive (and a good number have not met this test);
- economic development programs, which are usually measured in terms of job creation;
- creators of new technology, whether or not it is associated with economic development;
- tools for national economic development, as parks can act as "growth poles" (e.g., Science City in Korea) to help transform former manufacturing regions into high-technology areas such as Scotland's Silicon Glen; and
- sources of net value in cost/benefit terms, based on the net present value of benefits generated by the parks.

Dr. Luger said that his 1991 research covered more than 120 S&T parks in the United States. He concluded from interviews that economic development was the dominant motivation for the creation of these parks. As a result, he primarily defined success in terms of economic development for the local area: as the ability of a park to act as a local growth pole, helping companies to restructure and the area to redevelop, especially in former manufacturing areas that face the decline of traditional markets.

Metrics for Success

His primary indicator of success was net job creation, Dr. Luger continued. He operationalized this as the difference in job creation between regions with

S&T parks and control regions without S&T parks for the approximately 70 regions with S&T parks for which he has data.

On average, Dr. Luger noted, S&T parks are associated with a wide range of job growth rates. The Research Triangle Park showed the best results of all, with job growth 4.45 percent higher than control regions (a result that controlled for the impact of the business cycle on job growth). There is, however, considerable variation, with some regions actually experiencing negative growth vis-à-vis their control region.

Dr. Luger emphasized that these effects became clear only over a very considerable period of time (on the order of two decades), and it was important to allow enough time for these large investments to pay off. He also pointed out that the results did not capture any positive effects on job growth outside the immediate region, and that it would be very difficult to measure the impact on new technology development.

When considering the factors that accounted for success, Dr. Luger listed the following factors as critical:

- First is the ability of each park to develop a marketing strategy appropriate to the region in which it operates. This factor was clearly visible in the case studies developed in his research: The park tried to attract branch manufacturing plants, an approach that had not been adopted and probably would not have worked in Salt Lake City, Utah, for example. Similarly, a focus on particular disciplines should reflect the strengths of the local research community.
- Governance of the park by a research university seemed to make a difference, perhaps by connecting the park to university research in additional ways. The extent to which park personnel were adjunct professors, or park labs were located on university campuses, also seemed to increase the park's attractiveness.
- In each case, there was visionary leadership, such as that provided by the late Governor Terry Sanford in his support for RTP.
- Sponsors of each park displayed deep pockets and considerable patience. Payoffs emerged only after 10-20 years, when the park was well grounded.
- Good timing and good luck were also factors. Starting a park at the beginning of a long recession was not helpful.

The Case of Research Triangle Park

Dr. Luger stated that the Research Triangle Park was founded at a time when North Carolina was experiencing a substantial decline in manufacturing. Although there were research universities around the park, these universities were at the time suffering a significant outflow of talent, a brain drain. Graduates were not finding jobs in local high-technology companies and they were leaving. On the other hand, the area was seen by business leaders as the gateway to the expanding markets of the New South, while also having other advantages such as a considerable amount of available land. The park also benefited from strong, bipartisan leadership.

RTP acquired a number of major government tenants such as the Environmental Protection Agency, which located there partly because of the effective political leadership noted earlier, Dr. Luger continued. RTP also benefited from attracting IBM as its first major tenant. Other strategies employed by RTP included selling land to companies rather than just leasing it; providing a high level of services to its tenants; and making sure that there was a strong role for universities, as university representatives were on its governing board. Later, the state contributed to the development of two technology centers, one in microelectronics and one in biotechnology.

Dr. Luger pointed out that between 1984 and 1990, about 25 percent of new jobs in the area came directly or indirectly from the RTP, either through RTP businesses that would not have otherwise moved to the region, through purchases from suppliers and vendors in the area, through companies spun off from RTP tenants, or through indirect multipliers of spending by RTP personnel on goods and services in the region. In total, over a 24-year period the park appears to be responsible for 58,000 jobs that would not otherwise have been created in the region.

Dr. Luger added that job growth did not take into account the reputational effect that might have led firms to relocate to the Research Triangle region. By 1998 the region was a locus of high-technology employment, with numerous university labs and hospitals, and with one of the highest concentrations of Ph.D.'s per capita in the country. The region also become a leader in academic research, and the brain drain of the past turned into a brain draw. Between 1991 and 1996, 32 spin-off companies were formed by staff from regional universities. This reflected the existence of an entrepreneurial economy, as well as the impact of scientists and engineers from companies such as IBM and Nortel who had received severance packages and were reinvesting them as seed capital in new start-up companies. Finally, the liberalization of intellectual property regimes at the local universities had an important impact.

S&T Parks Abroad

Internationally, Dr. Luger noted, what local developers call S&T parks are located in virtually every country, regardless of the level of development. As economies grew, development needs changed, for example from airports to advanced research facilities. Service requirements from businesses changed too. The evidence also suggests that countries can leapfrog stages of economic development, if they are prepared to pay a very heavy economic price to do so.

Dr. Luger pointed out, however, that the RTP had been established during a period in which economic conditions were quite different from those prevailing today. The economy's current strength and the proliferation of S&T parks made the current environment more competitive, making success less certain.

Finally, Dr. Luger suggested that traditional pure economic development measures of success might be reconsidered to include longer-term infrastructure-building considerations, especially in areas such as New Mexico, where there are no large organization economies. One function of S&T parks is to replace certain economies of scale by providing shared infrastructure and services.

THE AUSTIN EXPERIENCE

Jurgen Schmandt
University of Texas, Austin

Dr. Schmandt said that he wished to offer a more impressionistic view of S&T parks, drawing heavily on his experience in Austin and Houston. His analysis covered four main areas:

- the importance of leadership,
- the importance of an "anchor,"
- location, and
- features that did *not* make a difference in Texas.

Early Developments in Austin

Dr. Schmandt began by reviewing the development of Austin's high-technology regional economy. He noted that when development began in 1971, Austin was a relatively small town of about 125,000 people, with a university of 40,000 students, and with state government as the main employer. The Texas economy was heavily dependent on oil revenues, with two-thirds of the state budget coming from the severance tax. As a result, the state economy tended to move countercyclically to that of the rest of the United States.

The key early players were IBM, Motorola, Texas Instruments, and Tracor, all of which focused on manufacturing rather than R&D in the Austin area. The year 1983 was a major turning point for Austin, Dr. Schmandt continued, as the Microelectronics and Computer Technology Corporation (MCC) decided that Austin would be a good choice for its headquarters. The decision brought 400 new jobs, but also helped to create a huge difference in people's perceptions of Austin.

Dr. Schmandt observed that the MCC decision had resulted from significant efforts from a range of leaders such as Henry Cisneros, then mayor of San Antonio, and George Kozmetsky, the dean of the Business School at U.T. Austin, who had started IC2, an incubator for entrepreneurs. The president of the university eventually became a strong supporter of university-industry partnerships. Leadership also came from the Department of Electrical Engineering and Computer Sciences. All were critical to Austin's success in attracting MCC. In addition, MCC was at the time specifically looking at second-tier research universities where its interests would not be overlooked, which fit well with the Engineering Department's number 14 national ranking at the time. Specific events that shaped Austin's development include:

- The university's decision to celebrate its centennial in 1983 by opening a fund drive to support 400 chairs, 50 in the Department of Computer Sciences and Electrical Engineering, Dr. Schmandt continued. This had a significant impact on the MCC selection committee.
- The election of Governor Mark White in 1983 was also a positive event. He was determined to seek a new high-technology base for the Texas economy and hence placed education high on his agenda. MCC, SEMATECH, and a major research division of 3M all came to Austin during Governor White's tenure.

Despite a severe recession in the late 1980s, the Austin high-technology sector continued to grow. Companies such as Dell Computers emerged, and the city's high-technology economy is now well established. Students now tend to stay in the area after graduating; indeed, local employment has grown to the point that wages sometimes accelerate rapidly. Although the overall Austin experience was positive, the state's commitment to the partnership waned and waxed with the occupant of the state house. Currently, under Governor Bush, the partnership is once again on the upswing.

The Experience in Houston

Dr. Schmandt compared the Austin experience with Houston, noting that promotion of regional economic growth in Houston adopted a quite different approach. Houston remains a world center for servicing the oil industry. Under the leadership of George Mitchell, a geologist for Fortune 500 companies, the Houston Area Research Center (HARC) was situated in a completely new town, The Woodlands. Planned for 150,000 residents, it had by 1998 reached about 50,000 after a period of significant struggle.

Mr. Mitchell wanted to ensure that The Woodlands would not be just a dormitory town. He therefore contracted with the A.D. Little consulting company for a strategic plan that laid out a detailed role for the S&T park in the development of HARC and The Woodlands. HARC was the creation of a consortium of four Texas universities, Dr. Schmandt continued. It was designed to pursue research projects that were too large for any single university. Initially, it aimed to focus on defense, but its most visible project was its role as a central node for planning and lobbying for the supercollider. Efforts failed to attract DOE contracts for magnets related to the supercollider. After this, it successfully turned to the possibilities of using magnetic technology to revolutionize the imaging industry by providing shielded magnets.

The original blueprint for HARC proved to be of little use, Dr. Schmandt concluded. Instead, HARC become a $50 million, 150-person contract research operation, which was a central node for high-technology activities among about 40 companies in the new town. Activities at HARC included information technology, environmental research, and energy research, all far from the original blueprint.

Conclusion: Factors that Mattered, Factors that Did Not

Dr. Schmandt suggested that, for both Austin and The Woodlands, the existence of a committed or even overcommitted leader, with an insistence on doing it and doing it right, proved critical. Clearly, the arrival of a major research anchor (MCC) changed the game for Austin, but this has not yet occurred for HARC. Austin's location close to a research university, but not to the Massachusetts Institute of Technology or another top university, was also helpful. What did not make a difference in either case, Dr. Schmandt observed, was the existence of the blueprint. Austin never developed one, and the blueprint for HARC was abandoned. In conclusion, Dr. Schmandt noted that the experience at U.T. Austin could be replicated, provided that there is a strong tie to a committed university, there is a strong leadership group (not just one person), and the timing is right.

DISCUSSANT

Irwin Feller
Pennsylvania State University

Dr. Feller said that his remarks, which would cover the role of Sandia's plans in the context of the role of the national labs in national S&T policy, would substantially reflect the "Press Report" concerning the allocation of federal R&D funds.[36] This report addressed the question of who should perform research during a period of constrained resources. In general, Dr. Feller observed, the Press Report has been interpreted as concluding that priority should be given to universities while having the national labs remain focused on their core missions. The Press Report also asserted that the national labs were not the most effective

[36] National Research Council, *Allocating Federal Funds for Science and Technology*, National Academy Press, Washington, D.C., 1995.

performers in technology transfer and regional economic development. These conclusions should frame the debate.

The Role of the Labs in National S&T Policy

In the context of national S&T policy, Dr. Feller stated that the national labs have clear and well-defined missions and that they have unique capabilities for performing these missions. As mission funding has declined, the labs have begun to seek new roles. In fact, discussions with lab directors made it clear that there is no domestic policy objective for which the labs do not have some sort of capability.

Dr. Feller strongly emphasized that in his view all activities beyond the traditional lab missions are best understood as a form of product diversification in an environment in which support for the core mission is declining. To the extent that the labs could perform these services better than other players, they could be supported, but he stressed that this is not their core mission.

In light of this, Dr. Feller proposed Feller's law: That every state has at least one sticky region; every state has some major federal facility (even if it is not a national lab), and each has a university with some research capability. The question in terms of national S&T policy is therefore whether federal funding should be tied to traditional peer-reviewed research projects, or whether federal S&T funds should be deliberately considered as a means of spurring regional economic growth, using whatever facility that state has to act as a "growth pole."

Dr. Feller stressed that he did not object in principle to the use of regional distribution as a criterion for helping to allocate federal funds. He believes that a legitimate case could be made for such a policy applying to all federal funding. The problem emerges when this question is considered piecemeal, in the context of a specific proposal for a specific S&T park. In his view, the issue has not yet been thought through.

Metrics of Failure

Rather than seeking to focus solely on the criteria for success, Dr. Feller focused on the question of the metrics of failure. He noted

- the absence of market metrics,
- the long incubation period for S&T parks, and
- the general absence of clear cutoffs for determining failure.

In conclusion, Dr. Feller reminded the audience, that first, not all partnerships succeed. And second, there are no criteria readily available to policy makers for determining failure. As a result, support of S&T parks is potentially a side-show in the context of national S&T policy, with high opportunity costs that are not being put on the table.

DISCUSSION

In response to a question, Dr. Luger noted that he had not looked specifically at any links between ties to a national lab and the success of specific S&T parks. However, such links were quite common in Europe and Asia and had been the basis for a number of very successful projects.

In response to a second question, Dr. Luger agreed that the liberalized university intellectual property policy that he referred to earlier in fact was better understood as a tightening of policies in support of exclusive licensees, ensuring that intellectual property was indeed reserved for their sole use. Dr. Luger's questioner suggested that there was a clear tension between the need for universities to remain open to the exchange of knowledge and at the same time to develop a more rigorous intellectual property regime through which to encourage entrepreneurs and help to retain faculty.

Kathleen Kingscott from IBM suggested that it was important to consider the impact of S&T parks beyond the immediate region in which they are located and specifically to consider the national effects. This approach might help to develop support for S&T parks in Congress.

Employment Effects

Dr. Joel Yudken asked whether S&T parks might not be simply moving aside workers in the existing low-skill manufacturing sectors; and replacing them with high-paying, high-technology jobs that are not open to the displaced workers. He wondered who the real winners and losers are in the growth generated by S&T parks.

Dr. Luger remarked that the effort to bring R&D to the RTP in North Carolina had been based partly on the belief that R&D would be tied to manufacturing and that manufacturing jobs would in the end also flow into the region. However, he noted that this had never happened and that the clustering of R&D facilities had exacerbated economic differences within the region. North Carolina was a good example, with the research economy juxtaposed against the much poorer rural economy. Silicon Valley offered a similar story, with heavy commuting costs imposed on lower-paid workers.

Training

Dr. Schmandt commented that, as far as Austin was concerned, the initial story was one of inward migration from outside the region. Over time, attention shifted to training workers for the information industry, including some major chip manufacturers. Training is now a high priority. He also suggested that the key lies not in the activities of the universities, but in the community colleges, some of whom have done excellent work in that area.

Ms. Kingscott of IBM noted that IBM's experience in RTP was so successful that, although employment had fluctuated, there are now 12,000 employees, and R&D activities had also been added. This success led to IBM's investment in another major manufacturing facility in Charlotte, all of which certainly benefited workers in North Carolina, which now has the second largest number of IBM employees in the United States.

The States' Role

Dr. Luger noted that the majority of states in the United States were not involved in strategic R&D activities, and that only 13 states have a strategic plan; S&T parks are often the result of seed capital funds developed by specific governors.

Dr. Schmandt said that in Austin the federal role has been primarily to allow a regional university to become a research university through a broad range of federal funding and grants. The state also began its own National Science Foundation-like grants program. Although the funds are welcome, he did not believe that they made any real difference. The key state role is to pay the salaries of professors.

Dr. Feller noted that the era of activist or entrepreneurial state economic development programs reflected the 1980s much more than the 1990s. The current reality is instead one focused on privatization and less activist government. In many cases, after an initial surge, states have fallen off in their participation in federal programs that require some matching state funds. Most states play the federal game and are seldom willing to put up money at the state level to create an infrastructure. For example, although training and building a high-productivity labor force would be a key engine of economic growth for the future, state appropriations for higher education have fallen for much of the past decade. Hence, there is a gap between the rhetoric of federal-state partnerships and the reality that involves both the governor's office and the state legislatures. Reluctance to provide state funding came about partly because the states did not accept that S&T parks were necessarily a good investment, and also because legislators saw the funding as simply special interest funding for universities.

The Need for Commercial "Spin-on"

Dr. Simon remarked that Sandia's primary mission will not erode, and that Sandia will continue to receive its share of the bipartisan $4.5 billion to be spent on the weapons stockpile. As a result, Sandia will continue to retain a range of major missions related to this objective, although the world of defense S&T has changed dramatically. Where once it existed in splendid isolation, there is now a tremendous push to ensure that ideas flow from the commercial world to defense. The new nuclear weapons mission is not to create new weapons, but to fully understand and remanufacture existing weapons, a mission that needs to draw on technologies that are available in the commercial world. There is therefore a mission requirement to have not just technology spin-off but also technology spin-on from the private sector. This requires a Sandia that can absorb ideas from the private sector, which in turn requires a vision of a wider technology infrastructure, which includes "technology receptors," such as S&T parks.

Panel II

Technology Transfer and the National Laboratories

Moderator:
Tom Mays
Morrison & Foerster

Dr. Mays suggested that the task of transferring technology from the national laboratories revolves around four key issues:

- mission,
- money,
- materials, and
- mental creativity.

He noted that transferring technology from a government entity was much more complex than transferring it from a university. There are commonalities between the two approaches, but the federal process faces additional issues related to agency missions and congressional oversight. Overall, Dr. Mays observed, the quality of the research is critical, and leadership is the *sine qua non* for successful transfer efforts. In that connection, he believed that the study currently under way at the National Institutes of Health would probably shed significant light on the effects of technology transfer and patenting on basic research.

Dr. Mays recalled that the Stevenson-Wydler Act listed as its first finding that "Technology and industrial innovation are central to the social, economic, and environmental well-being of the citizens of the United States. Further, technology transfer consistent with mission responsibilities is a responsibility of every laboratory science and engineering professional." This defines the context in which the discussion should begin. As a result, although regional issues are important, it is critical to take into account the national goals and objectives.

ORIGINS OF THE PARK CONCEPT

Albert Narath
Lockheed Martin

Dr. Narath said that he recognized the fact that, in general, successful S&T parks have been associated with the proximity of research universities rather than federal labs. A number of factors have contributed to this:

- federal labs have federal missions that constrain their activities,
- federal labs are harder than university labs to access,
- labs have been caught up in the national policy debate since 1989, and
- federal labs generally do not have the freedom to combine work for which they are being paid with entrepreneurial moonlighting.

Nevertheless, federally funded R&D centers play an increasing role in the development of S&T parks. Generally, their capabilities are complementary to those of universities, despite some overlap.

Looking at the national R&D enterprise, Dr. Narath noted that, although there are more than 700 federal research bodies, the top 25 or so account for almost all of the $25 billion in federal laboratory funding for science and technology. Of that, DOE labs are responsible for some $5 billion to $6 billion, with the two New Mexico labs accounting for about 10 percent of that total. Universities account for $21 billion and industry for $112 billion, of which $28 billion is derived from the federal government.

Dr. Narath noted that he believed the Press Report was very seriously flawed in that it did not take an in-depth look at the contributions made by the national labs. In contrast, he was optimistic about the S&T park enterprise, partly because he believed that the most interesting developments occur through the interaction of three elements, that is, universities, the national laboratories, and private industry. In any complex system, the exciting things occur at the interfaces, and contact between different organizations and disciplines can catalyze interesting developments.

One key element that has contributed to interesting developments in policy arena is the convergence between public and private science and technology interests, Dr. Narath asserted. He noted that public-private partnerships help to enhance mission performance as labs involve themselves in technology issues of great interest and value to private organizations. There is an opportunity through these interactions to create additional value for the taxpayer. Porosity, the ability of lab personnel to have frequent and productive contacts with the private sector, is also important in helping the labs retain competent staff.

In the case of Sandia, Dr. Narath continued, technology transfer has become an important element in the 1990s, and Sandia has accomplished a great deal.

The number and scope of partnerships, and the impact on both Sandia and the industrial partners, has been quite significant. One measure is the rapid growth in private sector investments in R&D undertaken at the lab, currently about $40 million per year for fully reimbursed research.

Dr. Narath also pointed out that the Sandia S&T park does not anticipate major federal investments. Success will come if the private sector sees sufficient value in closer relationships with Sandia. In general, the future of the S&T park is bright. In recent years, Sandia has focused on science-based engineering, a direct outgrowth of its basic mission, and of growing interest to private sector partners.

THE SANDIA S&T PARK PROPOSAL

Dan Hartley
Sandia National Laboratories

Background on Sandia National Laboratories

Dr. Hartley began by noting that Sandia is one of the country's premier research institutions and that it has fulfilled its defense and energy missions for 50 years. Sandia now employs nearly 7,500 people, of whom 1,800 hold doctoral degrees. He believes that these staff are among the best minds in the country, and that hiring and retaining people of this quality is a constant concern.

Sandia's primary missions have always been very clear, Dr. Hartley continued. On the military side, Sandia is responsible for the design of all parts of nuclear bombs except the nuclear package itself. In a system with more than 5,000 parts, this task requires extremely high levels of reliability. This mission now mandates the further involvement of universities and researchers outside the labs. Sandia's energy mission is quite similar, as once again reliability is a critical requirement.

In fulfilling these missions, Sandia developed a number of world-class facilities, Dr. Hartley observed. These include:

- the Microelectronics Development Lab,
- the Robotics Manufacturing Science and Engineering Lab,
- the Advanced Manufacturing Process Lab,
- the Integrated Materials Research Lab,
- the Integrated Manufacturing Technologies Lab,
- the Combustion Research Facility, and
- the Teraflop Computer.

Sandia's satellite facilities in California have been the home of Sandia's first public-private partnerships. These facilities have begun to change the institutional culture to one that is more open to outside researchers and organizations.

Sandia's dominant mission of the twentieth century—nuclear weapons—is about to change completely in the twenty-first century, Dr. Hartley said. Testing has shifted from the test site to the computer, which is revolutionizing how Sandia operates. Industry is going through the same transition, and Sandia could learn from industry's experiences. This shift also applies to the energy sector, where similar dramatic shifts in philosophy will be required.

Sandia's Evolving Mission and the Need for Partnerships

Sandia's management is now convinced that each mission will require partnerships, as Sandia can no longer provide all the required expertise, Dr. Hartley noted. Relations with outside organizations can range from a simple vendor relationship all the way to strategic alliances in which the partners support each other during difficult times and in which the partners share a common future. Strategic partnerships involve what Dr. Hartley called TEC^3, which stands for time, ethics, competence, capability, and commitment.

Developing this type of relationship is hard work, but many of Sandia's partnerships with industry are reaching that level, such as its partnerships with Intel and Goodyear.

The Sandia S&T Park

It is worth noting that the Sandia S&T park was not conceived by Sandia. Instead, the idea emerged from a discussion with one of Sandia's partners. The company approached Sandia with the objective of developing a strategic relationship in which the company would move some of its R&D operations next to Sandia in order to facilitate communications and permit personnel rotations. Dr. Hartley noted that Sandia now has approximately 300 industry partners.

Gaining commitments for the land was a somewhat complicated matter because of having to address the needs of multiple landowners, Dr. Hartley remarked. He noted that there were differences between the surrounding areas of Sandia, situated near Albuquerque, and those of Los Alamos, which were less developed. He also noted that New Mexico is the state with both the highest percentage of Ph.D.'s in the population and the highest percentage of high school dropouts.

Sandia has formed relationships with other research organizations based in Albuquerque, Dr. Hartley continued. Sandia and its research organization partners have differing motives for developing partnerships with industry. Sandia wants a place to house its Cooperative Research and Development Agreement (CRADA) partners, which are very different from the organizations being attracted by the University of New Mexico. However, Sandia is continuing to work closely with many of the other research organizations in New Mexico. Indeed, a rich cluster of research capabilities is emerging, Dr. Hartley said. For example, the University of New Mexico has demonstrated the fastest growth of research funding of all U.S. universities over the past five years.

Unique Features of the Sandia Park

The Sandia S&T park has some unique characteristics. First, industry came to Sandia. Sandia had not been trying to sell the model to its industry partners. Second, the S&T park is aimed primarily at Sandia's CRADA partners. Third, Sandia is working hard to ensure that the types of interaction being fostered at the S&T park are those that will contribute to meeting Sandia's primary missions. Fourth, the S&T park is creating choices for Sandia staff as Sandia starts to rotate staff into the facilities of its partners.

Looking forward, Dr. Hartley noted that, in June 1998, the S&T park would break ground on a building for Emcore, a long-standing Sandia partner from New Jersey, which is building its first on-site facility. As Sandia moves forward with the realization of the S&T park, management is addressing a wide range of issues, including:

- dealing with multiple landowners,
- institutional issues,
- infrastructure needs,
- finding anchor tenants for the S&T park,
- integrating work-force training into the S&T park,
- creating common support systems for tenants and Sandia, and
- integrating the Sandia S&T park into New Mexico's culture and infrastructure.

Perhaps most important is that the development of this park could be used as an experiment in public-private partnerships to shed new light on an interest we all share: how to increase R&D innovation in America.

DISCUSSANT

Kenneth Flamm
*The Brookings Institution**

Dr. Flamm said that his comments would cover the pros and cons of S&T parks and address some organizational issues. First, as background, he noted that

* At the time of the symposium, Dr. Flamm was a Senior Fellow at the Brookings Institution. He is now the Dean Rusk Professor of International Affairs at the Lyndon B. Johnson School of Public Affairs at the University of Texas at Austin.

the end of the Cold War and the downsizing of the nuclear weapons manufacturing establishment meant that the nation faced a choice: Either the United States could decide to reduce the size of the federal commitment to R&D, leaving the market to allocate priorities and hence accepting some significant transition costs; or it could take a more activist policy and add new missions to complement the shrinking core mission of the labs. This choice has not been definitively resolved, is very politically charged, and continues to lurk in the background of the discussion. Dr. Flamm also noted that one of the reasons that is advanced for supporting S&T parks is to house CRADA partners. However, not all CRADA activities at the national labs are very well thought out in terms of supporting the basic mission of the labs. He believed that three to four years earlier the labs had been somewhat indiscriminate in their search for partners to support the CRADA process. As a result, there are questions as to whether the CRADA process was itself the best way to support the labs.

The Benefits and Costs of S&T Parks

Dr. Flamm observed that S&T parks offer a creative way to drive resource allocations defined by the Cold War toward new configurations, a way of encouraging a voluntary transition of human resources out of the laboratories and into industry. As a result, the S&T park approach could reduce transition costs. Dr. Flamm said that S&T parks also offer an opportunity for the federal government to subsidize selected pieces of U.S. industry. This could be desirable where the social return on investment is greater than the private return. In particular, S&T parks could help the federal government to support mission-driven R&D with less immediate commercial applications.

Turning to the cost side of S&T parks, Dr. Flamm noted that, although subsidies are appropriate in some cases, it is important to seek out those areas that truly meet the criteria laid out above. It could be argued that these considerations played little part in Sandia's discussion to create a S&T park. Moreover, such subsidies could also take on a life of their own, Dr. Flamm cautioned, and as a result, there is a risk that such a policy would create a permanent entitlement program.

A Regional Mission?

Dr. Flamm also noted that the new approach, namely, adding regional growth to the roster of labs' concerns, would complicate the mission of the national labs by adding a subsidiary mission. As a result, he wondered whether S&T parks, as adjuncts to national labs, represent the most efficient way in which to support what he agreed are worthy objectives. In addition, Dr. Flamm suggested that it might be better to create a New Mexico regional S&T park that could serve all of the federal research facilities in the area. This would have the advantage of not being directly associated with any single institution. Concluding with some organizational issues, Dr. Flamm noted that it would be especially important to ensure that policy focuses on issues related to transitions and that it emphasizes the transfer of excessive resources from one area to another in a way that would minimize the cost to the people involved.

DISCUSSANT

Kenneth M. Brown
National Science Foundation

Key Element for Success: Technology Transfer

Dr. Brown said that he would focus his remarks on the question of whether the Sandia S&T park could succeed. Much of the discussion so far in the symposium has focused on economic results. However, he believed that it was more important to focus on the real reason for these types of projects, namely, technology transfer, which is the prime federal justification for supporting such a project. He noted that enticing firms from other regions into New Mexico has no merit at all as a national policy. Hence, the real objective should be the creation of a net gain for the nation by using Sandia's technology in the widest way possible. Economic gains are a necessary condition for the success of the Sandia S&T park, but only technology transfer constitutes a sufficient condition.

Dr. Brown observed that New Mexico is an unusual state. It is the number one state in the nation in terms of research intensity (research spending divided by the state's gross domestic product), and it also has twice as many Ph.D. scientists and three times as many Ph.D. engineers per capita as any other state. This indicates that there is likely to be a considerable amount of technology transfer, especially as Sandia's work is especially suitable for commercial application. At the same time, however, R&D in New Mexico is concentrated almost entirely in the federal labs; without them, the state would fall to almost last place among the states in R&D indicators. Hence, there are relatively few companies in New Mexico that can take advantage of Sandia's technology. As most firms entering S&T parks tend to come from within about 50 miles, this could indicate a problem. However, 25 percent of Sandia's CRADA partners are from New Mexico, and another 25 percent are from the adjoining states. Given these figures, Dr. Brown questioned whether there are many other potential local CRADA partners not yet already involved. The average distance of CRADA partners is currently about 1,000 miles from Sandia. As a result, he recommended that Sandia look well beyond its current list of CRADA partners.

In Dr. Brown's view, key issues for the future of the S&T park include:

- the extent to which government-supported CRADA research would be competing with the private sector,
- the extent to which spin-off companies would take valuable Sandia employees with them, and
- the need to develop a policy to handle foreign participants in the S&T park.

Overall, Dr. Brown considered that the critical issue is not how to create a new mission for Sandia, but how the S&T park could help Sandia fulfill whatever mission it is handed.

DISCUSSION

A participant noted that 23 start-up companies had already emerged out of Sandia's partnership activities, one of which has been acquired by Emcore, the New Jersey company now building in the S&T park. He added that Sandia's budget is currently $1.3 billion, and would probably shrink over time, which means that Sandia itself as a national lab would probably shrink as well. The issue, however, is not that of replacing one mission with another; the real question is how the Sandia S&T park could help to support whatever missions it is entrusted with. A closer interaction with the private sector could be part of that process. He rejected the notion that the S&T park should be seen as a way of supporting the transition for government workers to new projects.

Berkeley's Michael Borrus noted that in the past, the United States could always count on reaping most of the benefits from its investments in R&D. This was because the U.S. market is the largest and the most advanced, and U.S. companies are industry leaders who tend to produce at home before exporting abroad. The benefits of technology spin-off could therefore be largely captured by the U.S. domestic economy.

This scenario has changed over the past ten years for the following reasons:

- In a growing number of cases, foreign firms have caught up to the United States and might now be leaders in certain industries.
- Technology development has been increasingly occurring outside the United States.
- Foreign markets could be effective launch markets for new products.
- U.S. firms have globalized their R&D investments.

As a result, the United States, which has the most porous economy in the world, faced circumstances in which technology developed in the United States tended to flow out faster than foreign technology flowed in. Mr. Borrus therefore saw the need to develop policies and programs that would help the United States to more fully capture the benefits of the federal investment in R&D. Policies that link federal support to domestic production are one approach.

He concluded his remarks with several questions for Dr. Hartley and Dr. Narath: What are the top three companies that they want to locate at Sandia? Which activities did they want those companies to locate there? Why did they want those activities?

In response, Dr. Hartley said that the companies Sandia works most closely with are in a few sectors: defense aerospace, microelectronics, energy, and automation. Several companies among these are exploring relocation of R&D elements with Sandia. However, nearly all have asked Sandia to respect the confidentiality of these plans. One microelectronics company, Emcore, has committed and announced; another, Lucent, has said that Sandia can only refer to its commitment to be involved in the park.

As to the activities that Sandia would want these companies to locate at the park, Sandia seeks the presence of certain activities because they align with Sandia's principal strengths and competencies that have been developed through decades of investment. Sandia is interested in these activities because it is important to have industry reinvestment in these competencies to ensure that Sandia remains current with the market and allows Sandia to perform its missions.

Several participants asked if the research park is to be federally subsidized. The short answer, said Dr. Hartley, is no. There is no direct federal subsidy to the park. Most of the land is nonfederal, and the minor piece that belongs to DOE will likely be leased at market rates. Construction of buildings and infrastructure is a private venture as well. To be realistic, of course, the technology assets that attract the park occupants are the result of years of federal investment, but these assets are provided to users at full cost recovery. Similarly, Sandia's management time to participate in and lead the creation of the park is a part of Sandia's community outreach efforts, not a direct federal program charge. Moreover, as noted, Sandia believes that the interaction with the private sector will help to keep Sandia's capabilities on the cutting edge of technology and therefore contribute directly to all of Sandia's missions.

Dr. Schmandt asked whether the decision to develop the Sandia S&T park had already been taken or whether it still had to be made. He suggested that this would fundamentally shift the nature of the discussion. Dr. Hartley replied that the decision had been made to enhance Sandia's relationship with industry. Sandia is still exploring how best to do this, and the S&T park is an element of that strategy. If, and as the park concept evolves, Sandia wants to be sure that the park structured in a way to enhance innovation, technology codevelopment and mutual mission will benefit. Input from meetings such as this symposium can help.

Panel III

Institutional Design

Moderator:
Ernest Moniz
Undersecretary, U.S. Department of Energy

Dr. Moniz said that the DOE sees public-private partnerships as essential for a variety of reasons, including the development of new technologies. These partnerships also help to support the appropriate high-technology supplier base for the laboratories. The DOE is currently working through the process of developing some principles for public-private partnerships, and Dr. Moniz noted that the following principles have been advanced by Chuck Schenk, one of the national laboratory directors:

- Agreements must benefit both the government and industry.
- Unique lab knowledge forms the basis for successful collaborations.
- Unique lab facilities create opportunities for collaborations.
- Partnerships should be encouraged that create a public good.
- Direct use of federal R&D funds to benefit stockholders is inappropriate.
- Foreign involvement is appropriate to the extent that it provides aggregate benefit to U.S. taxpayers.

Dr. Moniz also raised the question of risk aversion in the context of public-private partnerships. Failed partnerships are bad because they have failed; federal funds are wasted. Successful partnerships can be criticized because private sector firms profit from the successes.

THE CONDITIONS FOR SUCCESS

Edward Malecki
University of Florida

Dr. Malecki noted that his research aimed to synthesize the current state of knowledge on R&D, economic development, and entrepreneurship.[37] He said that, in terms of developing criteria for success, the discussion so far has addressed the first level of success for S&T parks: economic or real estate success, measured in jobs and other economic criteria. A second level has not been discussed, namely, the creation of an entrepreneurial climate favoring start-up activities. At a third level, there is the European approach of aiming to create a sustainable milieu for innovation.[38] The latter approach is rarely discussed in the United States.

Starting with economic success, the main metrics would include the number of firms attracted to the park, the jobs created, and R&D organizations or R&D activities involved in the park. Usually these are measured locally (i.e., within the S&T park or an adjacent incubator organization). However, the existence of other S&T parks in New Mexico and even within Albuquerque means that Sandia's S&T park is facing direct competition for "real estate" success.

Dr. Malecki remarked that when considering the potential relocation of firms, there is a limited universe of potentially mobile R&D facilities. As a result, it might be difficult for new parks to achieve critical mass. Affiliation with a research university is essential because of its patience and deep pockets and partly depends on the institutional backing of Sandia and others in New Mexico's political circles.

Dr. Malecki also raised an important caveat, noting that the linkage between the local economy and a S&T park can be problematic. For example, in only two of seven regions studied by Rolf Sternberg were S&T parks directly related to regional economic success.[39] As a result, there can be no guarantees that the Sandia S&T park will have a significant positive impact on the New Mexico economy.

The seedbed criterion looked at the number of new firms created as the key metric, Dr. Malecki continued. This would involve a high rate of spin-offs from both Sandia and from the CRADA firms. These would need to be located in New Mexico. In addition, this high rate of spin-offs would need to be maintained, a

[37] For a broader review of these issues, see E. J. Malecki, *Technology and Economic Development: The Dynamics of Local, Regional and National Competitiveness*, 2nd edition, Addison Wesley Longman, London, 1997.

[38] R. Sternberg, "The impact of innovation centres on small technology-based firms: the example of the Federal Republic of Germany," *Small Business Economics, 2 (2), 1990, pp. 105-118.*

[39] *Ibid.*

factor that cannot be guaranteed during the early years of any S&T park. Naturally, knowledge generated by sectors with high R&D is expected to generate most of the new firms and thereby sustain innovation in a region.

Conditions in New Mexico versus Silicon Valley

As far as support was concerned, a range of developments is required to foster entrepreneurship, Dr. Malecki observed, and it is not clear whether New Mexico offers a sufficient number of them. They include:

- consultants and role models,
- available venture capital,
- practical business assistance and contacts for international marketing, and
- interfaces or gatekeepers between park firms and R&D organizations (universities or laboratories).

It was not clear to Dr. Malecki whether these supporting elements are in sufficient supply in New Mexico. Nevertheless, Dr. Malecki believed that all of these factors helped to create a milieu for innovation, characterized by a high degree of innovative interaction, cooperation as well as competition, and flexible adjustment to competition.[40]

The simultaneous emergence of these factors underpins the Silicon Valley model, an ecosystem for central entrepreneurship, Dr. Malecki said. This ecosystem includes links between small and large firms, reinvestment in new firms within the region rather than venture capital moving out into the national pot, the ability to "unlearn" old ways, institutional support for innovation and new firms, and destigmatization of failure. These factors add up to synergy, the elusive combination that constitutes the Silicon Valley environment, Dr. Malecki observed. Regionally, this required an industrial structure with strong interactions between firms, successful entrepreneurial role models, and in many cases an agglomeration of a large number of high-technology companies. The Albuquerque region now meets at least the minimum requirements, as it is larger than Austin was before its initial growth period.

Sandia and Albuquerque

As far as Sandia is concerned, Dr. Malecki remarked, there are significant regional constraints, namely, that branch plants and government labs generally

[40] Professor Joshua Lerner's findings in his review of the Small Business Innovation Research (SBIR) program grants to high-technology start-ups lend support to this observation. See J. Lerner, "'Public venture capitalist': rationales and evaluation," in *The SBIR Program: Challenges and Opportunities*, National Academy Press, Washington, D.C., 1999.

spark few spin-offs. It is worth remembering, even emphasizing, that in all cases, success came slowly, often after 20 years or more. Dr. Malecki suggested further that federal labs had generated relatively few spin-offs, and few of these had been manufacturing rather than consulting companies. Overall, there appeared to be little institutional support within the labs for spin-off companies. In Europe, research findings indicated that big national labs were incubators only when entrepreneurship, regional technology transfer, and interaction with other regional institutions were all part of normal operating procedures.

Turning to Albuquerque and Sandia, Dr. Malecki remarked that, although Sandia has the reputation as one of the most industry-oriented labs of the national weapons laboratories, this does not automatically ensure that technology transfer will be successful. As far as the urban agglomeration is concerned, Albuquerque is in relatively good shape: For example, it has better air service than either the RTP in North Carolina or Austin during their early stages. However, there are challenges. In particular, risk capital is still in very short supply. Moreover, there are few entrepreneurs, and therefore role models, and less dense networks for aspiring entrepreneurs. These might come in time, but it might require a generation for these local networks to develop.

Discussion

In response to Dr. Malecki's observation about technology transfer, Dr. Hartley affirmed that technology transfer is a critical objective and is considered an integral part of Sandia's mission. Another participant remarked that there had been some significant developments over the past year in venture capital in New Mexico, with the creation of a state-backed venture capital fund. One percent of the state pension fund was put into the fund, which was then invested with venture capital companies that had offices in New Mexico.

In the context of questions about labs and entrepreneurial activities in Europe, a participant noted that the European business environment did not appear to be especially supportive of small firms, although it is true that some sectors are more successful than others. For example, Helen Smith's comparative studies on biotechnology in the United Kingdom, France, and Belgium indicated that institutional culture made all the difference in the relative rankings of different parks in different countries. Dr. Malecki observed that, although Smith's studies covered only a relatively few successful firms, the Technopolis project in Japan had almost no success in terms of entrepreneurship, despite the presence of many government labs. In his view, the commonality across countries seems to be that institutions that are clearly linked to government tend to be less entrepreneurial than those rooted in the private sector.[41]

[41] Even in the case of consortia firmly rooted in the private sector, such as SEMATECH, the number of start-up companies associated with cooperative activities appears limited. Paradoxically,

GOVERNMENT, UNIVERSITY, AND INDUSTRY LINKAGES

Adriaan M. de Graaf
National Science Foundation

Industry-University Programs at the National Science Foundation

The National Science Foundation (NSF) supports more than 100 university centers, such as Industry-University Cooperative Research Centers (IUCRCs), State-IUCRCs, Engineering Research Centers (ERCs), Materials Research Science and Engineering Centers, Science and Technology Centers, and Minority Research Centers of Excellence. Total NSF funding for the centers is about $200 million, whereas industry support amounts to about $100 million, in kind, in cash, and in personnel. The NSF also provides about $30 million for Grant Opportunities for Academic Liaison with Industry, supporting links between university students and their counterparts in industry. This program is matched with about $25 million from industry.

Dr. de Graaf said that the NSF also offers a wide range of other programs, supported by more than $500 million in NSF funding, matched by more than $50 million in industry contributions. Total NSF activity involving industry was approximately $1 billion, about one-third of NSF's total budget. Taking into account private sector funding sources, the leveraging was almost 100 percent.

Some of these programs, such as ERCs, require interactions between universities and industry, and others encourage such interactions, Dr. de Graaf continued. Most happened naturally between researchers and their students and industry colleagues, following from personal connections. These informal connections often generated research collaborations and included joint education and training activities of great future value to students in particular. These interactions frequently involve large companies.

Two Cases: The Center for Ultrafast Optical Science and the National High Magnetic Field Laboratory

The Center for Ultrafast Optical Science (CUOS) at the University of Michigan develops and produces high-power lasers to study fundamental processes in matter. The CUOS has close connections with 13 industrial companies, generating daily interaction between scientists and students. Dr. de Graaf observed that many students have found subsequent employment in industry, and that the CUOS

consortia with less-successful technology transfer mechanisms than SEMATECH may generate more start-ups. MCC is perhaps an example of the latter type. See J. Horrigan, "Cooperating Competitors: A Comparison of MCC and SEMATECH," monograph, National Research Council, Washington, D.C., forthcoming, pp. 8-9.

research has also led to spin-off companies and hence new jobs. Work on the application of lasers in corneal surgery provides one powerful example of the CUOS's work.

Citing another example, Dr. de Graaf described the National High Magnetic Field Laboratory (NHMFL), a collaboration between Florida State University, the University of Florida, and Los Alamos National Laboratory. It is the most advanced facility of its type in the world. A user facility with in-house research programs, NHMFL offers educational and outreach programs. NHMFL is also a strong federal-state partnership and has important industrial involvement and significant international connections. The Tallahassee component is located in the Innovation Park Research Complex.

Dr. de Graaf concluded with a number of observations and questions. He noted that diversity seems to work in this field, insofar as there does not seem to be a single dominant model for university-industry interactions, although it is true that large companies tend to dominate ties to universities. There is, however, a mismatch between the time scales of university and industry interests, a problem that he thought might partly be addressed by enhancing master's degree programs. His concluding questions concerned the role that the NSF might play in supporting university partnerships with small companies, and he expressed his interest in having subsequent panelists and commentators address this issue.

Technology Transfer at the University of New Mexico

Charles Wellborn
University of New Mexico

Mr. Wellborn opened his remarks with a review of the S&T park at the University of New Mexico (UNM). The park is located close to the UNM campus and has seven buildings, six owned by the university and one by Lockheed Martin. Established in 1987, private tenants include Sandia, Batelle, and a medical start-up company. The Science and Technology Corporation at UNM, of which Mr. Wellborn is president, is a legally separate entity from the S&T park at UNM and the university itself. The corporation is, however, chartered by the regents of the UNM and serves as the licensing operation for the university. The corporation was established in 1993.

Mr. Wellborn observed that the UNM S&T park is oriented toward encouraging students and faculty interaction with the commercial technology process, using the numerous university researchers on site at the S&T park. The university has also recently helped to develop an incubator system with three spaces. So far, some six to eight companies have joined this incubator system, along with ten smaller companies. The UNM S&T park was built at a time when many such parks were being built across the country, with the idea that if the park was built, tenants would be found. He now believes that the process was considerably harder than that. The development of an incubator system reflects the recognition that proactive efforts are necessary to attract tenants.

Advantages of the Sandia S&T Park

Mr. Wellborn said that he thought Sandia does bring some advantages to its S&T park, which differs from the UNM park concept in that it is open to manufacturing. He also noted that it would be possible for the UNM S&T park to attract smaller tenants (5,000-10,000 square feet) if the park had the resources to construct a building to house them on a speculative basis. However, this approach is not practical for the UNM park, and the Sandia park could therefore fill this gap.

The Importance of Venture Capital

It is clear that venture capital is badly needed in New Mexico, Mr. Wellborn continued. He was pleased to note that there has been some recent improvement, as the state endowment fund now has $8 billion available, which in turn has attracted four more venture capital companies to set up offices in New Mexico. As other speakers suggested, guidance, focus, and discipline from venture capitalists are critical components, and their absence helps to explain why relatively little commercialization has taken place so far in New Mexico. Mr. Wellborn remarked that, as the state resolves the incubator and venture capital issues, critical mass could be achieved that would allow for significant increases in commercialization.

DISCUSSION

In response to Dr. Schmandt's query as to whether faculty were supportive of the UNM S&T park, Mr. Wellborn said that there have been buy-ins by certain elements of the faculty. Much of the work is focused on a few centers, notably microelectronics and medical technologies, and it is now starting to accelerate.

Licensing

A participant asked how intellectual property issues are handled at the university and the park. Mr. Wellborn answered that his office is responsible for licensing what his group considered to be winning technologies. He believed that it would be very hard to make commercial agreements without accepting the need for exclusive licensing, and his office did indeed accept such agreements.

Dr. Moniz remarked that licensing issues are relatively straightforward in cases in which federal funding is involved; however, the issues are not so clear in cases of university-industry partnerships. Dr. de Graaf observed that the NSF has relatively little contact with the licensing process. In response to a question from a participant, Mr. Wellborn noted that the objective is to develop long-term relationships with industry partners. Dr. Moniz noted that even at MIT, where the licensing process is mature, industry-sponsored research generated far more funding for university research than did licensing.

Dr. Wessner asked how the DOE's policies might interact with the labs, the NSF, and universities to enhance the supply of qualified people to a park, and also to help exploit developments coming out of the park. Was any integration envisaged in which NSF grants might help to support education and training activities such as Sandia's S&T park?

Mr. Wellborn noted that the UNM park shared some interests with Sandia, for example, expanding the supply of venture capital, even though there are areas in which they competed. Dr. Moniz said that it was possible that the DOE might have a partnership with companies operating in the Sandia S&T park, but the DOE does not of course have a policy to develop such partnerships in particular. He thought that companies spinning off from Sandia might be better aligned with the basic mission of the DOE, but that would be a company-by-company decision.

Small-Firm Interaction with Universities

A representative from Intel, Dr. Carmen Egido, asked if there were any active programs to foster interaction between small firms and the universities. Dr. de Graaf replied that the NSF did not at this point have such programs, but that NSF was very interested in finding ways to address this issue and hoped to hear from participants and others on this subject. Dr. Moniz said that he had two anecdotes to offer on the subject of small companies. The NSF has a very successful Materials Science Center at MIT, and that center has spun off a number of small companies. He noted that much of the research that led to these spin-offs came from discretionary funding controlled by the director of the center, rather than from traditional peer-reviewed research that accounts for the bulk of NSF funding. This could be a lesson for the DOE labs as well. Discretionary funding tends to be somewhat more opportunistic.

Second, Dr. Moniz remarked, there is the Experimental Program to Stimulate Competitive Research (EPSCOR) program through which a number of relatively research-poor states compete for federal funding from several agencies, including DOE and NSF. The EPSCOR program in Bozeman, Montana, generated seven to eight spin-off companies, on the basis of $2 million per year in research funding. He noted that the EPSCOR program allows projects to compete in a smaller pool, but it also requires that the states match federal funding at a one-to-one ratio.

INDUSTRY VIEWS

Papken Der Torossian
Silicon Valley Group, Inc.

To put his remarks in perspective, Mr. Der Torossian noted that he is chairman of the Silicon Valley Group Inc. (SVGI), a public company that manufactures semiconductor equipment. Fifty percent of his business is derived from lithography equipment; this is up from zero in 1990 when, as a small $100 million company, SVGI purchased Perkin Elmer, a prominent player in the lithography market.

In 1992, when IBM was experiencing financial difficulties, it canceled orders for SVGI machines, creating difficulties for SVGI because makers of lithography machines do not ship in large volume. At the time, Intel was not a customer of SVGI either. However, by June 1993 Intel had declared SVGI's lithography equipment the "best of breed," and was also increasingly aware of the need to provide leadership in the development of technology. In 1994 Intel invested in SVGI, and by 1998 the leading six layers of the semiconductors made at Intel, IBM, and some other leading companies used SVGI technology. In short, SVGI was by now designed into the production process by the major manufacturers of semiconductors.

From these experiences, Mr. Der Torossian concluded that there are a number of ingredients for success. These include:

- entrepreneurial commitment,
- technology leadership,
- supportive customers with a bias to help (although R&D funding from SEMATECH had been helpful, it was only useful if SEMATECH members had a bias toward buying the machine that the R&D helped develop), and
- volume production and sales.

In conclusion, Mr. Der Torossian emphasized that his company's development benefited from the resources of national labs and universities such as MIT, but that working directly with his customers proved most important of all.

Research and Development at Procter & Gamble

William James
Procter & Gamble

In opening his remarks, Mr. James reminded the participants that Procter & Gamble is the twentieth largest corporation in the United States. What is less well known is that it is the seventeenth largest investor in R&D, at $1.6 billion annually, more than companies such as Xerox, Du Pont, 3M, and Kodak. The company has made 50 consecutive years of year-to-year increases in R&D investment, which is associated with 50 years of increasing profits. He noted that companies with healthy balance sheets tend to invest more in R&D, and that companies with more investments in R&D tend to do better financially.

Overall, industry funds about 65 percent of all R&D in the United States, with about 75 percent of the research taking place in industrial labs. Research in industrial labs has grown from 40 percent over the past 25 years, a trend that seems likely to continue. Despite concerns about the demise of industrial research over the past three years, investment in R&D has grown at 10 percent annually, after a flat period in the early 1990s.

Continuing, Mr. James noted that U.S. R&D remains heavily concentrated in large corporations. About 400 corporations in the United States undertake meaningful R&D; the top 25 comprised 50 percent of all U.S. R&D, whereas the top 50 companies accounted for 75 percent of total industry R&D. Over the past three years, these large corporations have, if anything, accelerated their commitment to R&D by increasing their R&D budgets faster than the rate of inflation.

After the downsizing of the 1990s, corporations had healthy bottom lines and were more focused on top-line growth, which implied the development and marketing of new products and services, Mr. James continued. Basic research in major corporations is now more focused, and smaller corporations, which he suggested often did not do basic research very well, have in many cases dropped out altogether.

Management of R&D

One important development is the shift in R&D management from corporate to business unit support, Mr. James observed. This tends to tie labs more closely to the business. Major corporations have also increased their R&D facilities abroad, at about the same speed that foreign corporations have set up units in the United States. Closer links are also developing between technology and business planning. As a result, the disconnection between research and business issues has at least in part been closed over the past 20 years. This tendency has also been supported by the growth of concurrent engineering.

Portfolio management has also become more widely applied, Mr. James noted, as companies seek a more systematic way of deciding where to place corporate bets. Companies are also looking for real-time measures to ensure that they are tracking R&D effectively. However, Mr. James added that the evaluation process remains troublesome. For example, Procter & Gamble has numerous metrics to measure R&D effectiveness, but if all of the metrics were implemented there would be little time for actual research.

Mr. James said that the nature of corporate knowledge has changed profoundly, from an era in which middle managers controlled the information flow, and in the process guaranteed themselves jobs indefinitely, toward the current, much more democratic environment, which has resulted in a thinning of organizational hierarchies.

Partnerships

Another development is the push toward partnerships. Companies such as Procter & Gamble are increasingly looking for technology and partnerships that will fuel future growth. Mr. James added that areas of specific interest to Procter & Gamble include biotechnology, medical technology, and information technology. Sensor technologies and smart products are also a focus.

No company is able to produce all of the technology they require in-house in the current environment, Mr. James observed. At the same time, no company can predict where successful technologies will come from. As a result, Procter & Gamble is expanding its partnerships with universities, federal labs, standards coalitions, and suppliers. Currently, industry invests slightly over 1 percent of its R&D budget in universities. Although the economy continues to be healthy, Mr. James said he expects to see more corporate investment outside corporate labs. He also observed that, from a corporate perspective, there is little difference between investing with university partners or with lab partners. What matters is investing at the cutting edge.

Criteria for Success

Mr. James suggested that the following criteria are likely to be critical for the success of industry collaboration with national labs or universities:

- strategic focus;
- timely research, despite partners' different time frames;
- effective metrics;
- value to both parties; and
- intellectual property issues, which are becoming worse not better. For example, Procter & Gamble was forced to abandon a proposed major project with a large university because, after a year of negotiations, it was unable to resolve intellectual property issues. It is necessary to develop a favorable environment for intellectual property, which means some period of exclusivity in which to recoup the company's investments.

In his view, leading corporations are refocusing on corporate growth and on the technology-based innovation required to grow the top line. To accomplish this goal he expected that R&D spending would continue to increase. This in turn would inevitably lead to broader partnerships with universities and federal labs.

Finally, Mr. James stressed that it is important to get the bureaucrats out of the laboratories, so that the researchers can do their work.

In answer to a question, Mr. James noted that Procter & Gamble is more interested in accessing technical talent than in leveraging additional funding from universities or federal labs. Although equal funding would be a positive thing, this has not been typically the case in the past. Currently, Procter & Gamble has invested $20 million in basic research at more than 95 universities and is willing to continue to do so as long as this funding provides access to leading researchers and an opportunity to exploit the results.

In this context, Mr. Der Torossian observed that university professors seem to want the security of university tenure and the profit of an entrepreneur. This does not usually work.

DISCUSSANT

Joel Yudken
AFL-CIO

Dr. Yudken noted that labor traditionally has not paid a great deal of attention to S&T parks and indeed to S&T issues, whereas the high-technology community has paid correspondingly little attention to labor.

Labor's Concerns

Labor's real issue is how these activities affect working families, in particular in circumstances in which tax dollars are being used, Dr. Yudken said. Labor views S&T parks as regional development strategies that could generate technologies that affect the quality of life. S&T parks also offer opportunities for increasing access to technologies. On a very broad level, the AFL-CIO and its affiliates are looking at a range of issues that could provide context for examining S&T parks. Labor has had a long-standing and strong interest in education and training and also in related immigration issues in which labor opposed expanded immigration of technical staff, preferring instead to train U.S. workers.

Dr. Yudken noted that labor's interests in the S&T park could begin with the people who work in such parks, on jobs including construction for low-income and low-skilled service workers, as well as high-skilled jobs. He observed that many high-technology areas have pockets of low-skilled workers, often immigrants, and he wondered about the implications of S&T parks for these workers. To what extent is there a commitment to providing education and training for these workers so that they can get into high-technology jobs?

Regional Planning Issues

Beyond the local community, there are regional, state, and intra-state concerns, Dr. Yudken continued. In Pennsylvania, for example, the economy in some areas is being supported by old-line manufacturing companies that must adopt technology to remain competitive. How do investments in high-technology clusters around the research parks and universities help companies in more remote areas of the state economy? It is important to answer these questions to ensure that policy makers are not simply relying implicitly on a trickle-down model to ensure that economic benefits are more widely distributed; otherwise, it is possible that growing areas of the country will find themselves excluded from the emerging high-technology economy.

At the local level, the AFL-CIO is increasingly interested in becoming involved at the planning stage in economic development projects such as S&T parks, Dr. Yudken added. In particular, the AFL-CIO is interested in projects that would help to transfer technology to the community. Projects rich with technology transfer to the community could help to stimulate economic development in low-income areas, provided that policy makers do not limit investments in S&T parks only to those areas that are already relatively well off.

Panel IV

Operational Challenges: Opportunities and Contributions, Funding and Governance, Cost-Sharing and Cost Recovery, Intellectual Property, and Facilities Access

Moderator:
W. Clark McFadden
Dewey Ballantine

Challenges to Successful Government-Industry Partnerships

Mr. McFadden noted that, in his experience, putting together significant government-industry partnerships is very difficult. The main problem is that the government does not know how to do it very well. Companies such as Procter & Gamble have a great deal of experience, know clearly what they are looking for, use partnerships constantly in their business, and have clear goals for each partnership. Government officials find it harder to take the risks that are inherent in a R&D partnership.[42]

Operational Issues

Operational issues break down into a few reasonably well-known categories, Mr. McFadden continued. First, there are issues related to the technology that partners bring to the partnership; second, there are issues related to the structure of the partnership, which could range from actual cooperative research, to complementary activity, to sponsored activity.

In addition, there are a number of key concerns that labs would have to address to satisfy commercial participants:

[42] This reflects the uncertainty that is a part of any R&D undertaking. Kenneth Arrow first made this observation in "Economic welfare and the allocation of resources for innovation," in Richard Nelson. Ed., *The Rate and Direction of Inventive Activity, Princeton: Princeton University Press, 1962.*

- justifying the cost of the partnership;
- specifying the deliverables;
- resolving problems related to intellectual property rights, which would require balancing commercial needs for exclusivity with government insistence on broad technology transfer (the latter might require something less than an exclusive license); and
- addressing specific issues related to public investment in background intellectual property and how it might be commercialized.

Mr. McFadden wondered how partnerships could be brought together through the creation of common interests and how they could be sustained over time, a critical question especially when things do not go right.

Finally, the political dimension has to be considered, Mr. McFadden concluded, and that could mean resolving questions related to the national benefits of activities focused at the state or regional level. The typical political view is to look for local manufacturing jobs when deciding whether these investments are appropriate. However, there are important questions about the national-level impact of technology development grounded in the United States.

SEARCHING FOR APPROPRIATE MODELS FOR THE SANDIA S&T PARK

Michael Borrus
University of California, Berkeley

Mr. Borrus observed that there is a real opportunity to be strategic and selective in creating the Sandia S&T park. Rather than seeking to emulate Silicon Valley (which, although the recipient of careful thinking immediately after World War II, has more recently benefited from numerous factors including a considerable amount of serendipity), it might be better to look elsewhere for appropriate models.

Foreign Models

One possibility is the Economic Development Board (EDB) of Singapore, which has adopted a strategic and selective approach, Mr. Borrus observed. This approach is based first on a very clear vision of what the EDB wishes to accomplish inside or outside Singapore, in terms of which industries it wishes to help build, what value-added it is seeking, and which individual companies could help to accomplish these objectives.

Second, the Singapore EDB has developed an excellent understanding of the industry dynamics for the firms that it is seeking to attract. For example, when it knew that GE was likely to need a new advanced materials plant, and would likely site it in Asia to meet booming regional demand, it tailored a presentation specifically to GE and specifically to advanced materials facilities.

Strategic Assets

Given that companies apparently need access to the specific technologies and facilities available at Sandia, Mr. Borrus observed, this creates a set of strategic assets for Sandia. However, these assets can only be exploited effectively if Sandia focuses on its strategic opportunities. Hence, his critical question is: Which three companies does Sandia wish to attract to the S&T park? The discussion has to be that specific and focused in order to capture the strategic possibilities available. Given that the bulk of R&D in the United States is undertaken by a handful of large firms, and that the Sandia S&T park would need to attract one or two of these firms to act as anchors for the park, it would be critical for Sandia to customize its pitch to specific firms and facilities.

The False Dichotomy between Large and Small Firms

Mr. Borrus noted that the policy debate continually adopts a false dichotomy between small and large firms. Small firms are generally seen as more innovative than large firms. For example, much of Silicon Valley's economic success can be traced to the creation of new firms, some of which remain small or fail, and some of which grow into large ones. Yet the environment that generates a rapid pace of small business creation does depend, to a considerable extent, on the existence of successful large firms. Indeed, it is the interaction between small and large companies that really creates the innovation.[43] Small firms are the suppliers of the skills, technologies, components, and subassemblies, etc. that are required by the large firms, depending on the specific industry concerned. Although bringing in large firms might help to create an environment in which to nurture smaller firms around them, large and small firms should not be seen as a dichotomy. It is the interaction between the two that creates long-term economic growth.

Similarly, whereas most economic development plans focus on the *producers* of technology, *users* of technology play at least as important a role in defining the development trajectory of these industries, Mr. Borrus remarked. To take soft-

[43] In describing the Silicon Valley case, AnnaLee Saxenian observes that these interactions "defy sectoral barriers: individuals move easily from semiconductor to disk drive firms or from computer to network makers. They move from established firms to startups (or vice versa) and even to market research or consulting firms, and from consulting firms back into startups." Saxenian, *Regional Advantage, op.cit.* pp. 96-97. For a discussion of Intel's evolution and the company's impact on the Silicon Valley region, see Michael S. Malone, *The Microprocessor: A Biography*. Springer Verlag/ Telos, Hamburg, Germany 1995.

ware, for example, although there are large clusters of software companies around the big producers such as Microsoft in Seattle, most software development is clustered around companies spun out by companies that use that software, in financial services, for example, or large manufacturers. In New York, for example, the software industry that is built around the financial services industry is a much larger employer than all of the software developers that are consciously built around the software companies of Silicon Valley. Hence, the search for companies needs to include the users of technology as well as technology producers.

Potential International Synergies

Several speakers have noted that technologies complementary to the commercialization of U.S. technology exist outside the United States as well, Mr. Borrus commented. Some technical specializations abroad are marginally or even completely different from those existing in the United States. It is also important to see that the overall success of the project would to some extent depend on the creation of local skill sets that could be projected globally, as for example in the case of Bangalore's software industry. Identifying the right foreign partners would bring several advantages, notably complementary capabilities that local firms do not yet have. This might also help to tap broader distribution networks in foreign markets that could not otherwise be accessed.

Community Issues

Mr. Borrus observed that there could be some negative externalities involved in the creation of S&T parks, for example the creation of two-tier income structures. Clearly, it would be important to involve the local community in order to address or mitigate those problems, without substantially burdening the project. If Silicon Valley ever grinds to a halt, it would do so because of externalities that had nothing to do with technology, such as housing costs, traffic congestion, or inadequate public infrastructure.

Finally, as Mr. McFadden noted, having a consistent and predictable intellectual property licensing strategy, something the laboratories were not well known for, would be useful in the case of Sandia's S&T park. Mr. Borrus concluded by echoing the call from Dr. Feller and others for effective benchmarks and metrics with which to evaluate performance of the park over time.

GETTING THE MOST OUT OF GOVERNMENT–INDUSTRY PARTNERSHIPS

John Jennings
Office of Senator Jeff Bingaman

Mr. Jennings said that, on the basis of his past experience at the Defense Advanced Research Project Agency (DARPA), a number of principles need to be clearly understood:

- It is critical to start by defining the interests at stake for the agency, in relation to the agency's mission. Without a clear view of that self-interested perspective, it is hard to avoid confusion.
- Once clearly defined, the means of approaching these interests should then be more flexible, although flexibility remains a problem with most government bureaucracies.
- Whatever approach is adopted, it is critically important to choose sound projects using merit-based and not political selection criteria.

The problem is that any large institution, especially a government institution, finds it hard to be flexible, Mr. Jennings noted. Government agencies like to have and to follow a set of rules. DARPA has been successful largely because it is small and hence much more flexible.

In the U.S. system of government, questions are inevitably raised about private profits from taxpayer-funded R&D, Mr. Jennings observed, especially in publicly funded projects that are flexibly administered with few rules. The best protection against such questions is merit-based project selection.

Cost Sharing, Intellectual Property, and Foreign Access

As far as cost sharing is concerned, DARPA learned that it pays to be hard-nosed, Mr. Jennings concluded. It is in any agency's interest to know if its partners are at significant risk, which normally means financial risk. In-kind contributions are useful, but do not have the same impact as cash investments.

With regard to intellectual property, Mr. Jennings noted that the agency's fundamental interest is to ensure that its inventions eventually reach the market-place. To do so could require temporary time-limited exclusive licenses or other arrangements that could in some cases be outside the framework of the Bayh-Dole Act. The freedom to be flexible is important, as is thinking through these issues carefully.

Foreign access is perhaps the hardest issue of all, Mr. Jennings stated. The agency's interests might help to define the degree of appropriate foreign access, so thinking through these interests very carefully is critically important. However, it is often hard to do that effectively in the time available. Decision processes should be fast, and as simple as possible, Mr. Jennings said. It makes little sense to provide an incomprehensible solicitation that avoids telling recipients the actual technology being sought under the belief that this might be perceived as unfairly favoring one company over another.

Finally, although Congress is not especially comfortable with the idea, government actors have to be poised to seize opportunities quickly, Mr. Jennings concluded. Discretionary funding is unpopular in Congress, and a one-year budget cycle is not best suited to partnerships with commercial enterprises.

THE LEGISLATIVE CONTEXT OF SANDIA'S S&T PARK

James Turner
House Committee on Science

From a congressional staff perspective, the Sandia S&T park initiative is part of a very positive trend. Twenty years ago, the most contentious element in the DOE authorization bill was the DOE patent clause, which exemplified the profound differences of opinion between those on the left who wished to maximize the return from every federal dollar and those on the right who criticized what is now called corporate welfare (i.e., the belief that the patenting of inventions subsidized by federal R&D funds gives an unwarranted government preference to the beneficiaries). In 1980, the Bayh-Dole Act changed the mainstream view 180 degrees, to the point that friends of government-industry cooperation have been on top, although sometimes only tenuously, ever since.

The 1982 renewal of the Oak Ridge contract was another turning point, Mr. Turner observed, because for the first time the request for proposals insisted on an assessment of the impact of the operating contract on the local community. This changed how corporations and other institutions approached working with the labs.

Perspectives on the Sandia Proposal

Mr. Turner proposed that projects such as the Sandia S&T park initiative should be viewed from four perspectives:

- From an industrial perspective, it is critical to speed the decision-making process to match that of industry.
- From a national security perspective, we should recognize that Sandia would continue to be a national security lab for the foreseeable future. This role has significant implications for what Sandia could, and could not, do and sharply differentiates Sandia from other laboratories and universities. For example, security concerns would certainly condition any

decision to bring in foreign companies if only because perceptions play a disproportionate role on security matters.

- From a domestic competitiveness perspective, there are necessarily only a limited number of opportunities to cooperate with Sandia. Hence, fairness and the perception of fairness would be critical for protecting the program from the complaints of excluded companies.
- From an international competitiveness perspective, if Sandia were to bring a foreign company into the S&T park, it would be necessary to show that the company brings some unique skill or resource needed for the project, one not easily available from domestic firms.

Mr. Turner also outlined three perspectives that he hoped would *not* be used for assessing Sandia's S&T park activities, namely:

- the basic research or university perspective, in which the park may be expected to engage in a significant amount of curiosity-driven research. This is not nearly as helpful as the industrial model with its focus on commercialization;
- the Cold Warrior perspective, i.e., that the Sandia S&T park, simply because of its physical proximity to the Sandia National Laboratories, should have a national security focus ; or
- the DOE bureaucratic perspective, i.e., that the S&T park be assessed using metrics (e.g., CRADAs) that DOE may use in evaluating its own activities.

DISCUSSION

Dr. Hartley noted that there are indeed significant security concerns regarding laboratory employees finding projects outside the lab. In addition, during the long period in which AT&T operated the labs on a no-fee no-profit basis, management had no incentive at all to encourage spin-offs or other commercially oriented activities.

When Lockheed Martin took over management of Sandia in 1993, Dr. Hartley continued, part of the negotiations concerned the need to focus on regional development. Lockheed Martin created the Technology Venture Corporation, which was designed to support spin-offs from the labs. Since starting the program, more than 20 companies have been spun off, generally quite successfully. Senior lab staff have also become much more involved in activities within the region and in Albuquerque, and cooperative activities are becoming more coordinated across the region.

Partners

Dr. Hartley agreed that the international issue is indeed difficult. Sandia is learning to differentiate between facilities at the core of the nuclear weapons mission—those that are intermediate and those that are outside the core mission. It is significant that all of Sandia's advanced research buildings are situated outside the lab's fence. With regard to the selection of companies for the park, Dr. Hartley agreed that it was necessary to target specific companies both as anchors for the project and as strategic partners in relation to Sandia's core missions. A process for doing so is already in operation within Sandia.

One participant noted that the S&T park would generate serious political problems unless Sandia could clearly establish that the S&T park supported the lab's core mission. Although collaboration is common practice in industry, people in policy-making positions have to be convinced about its relevance to Sandia's core strategic mission. In response, Dr. Hartley noted that a recent Congressional Research Service report examining CRADAs had referenced two studies that supported the view that CRADAs contribute to the existing mission of the national labs.

Dr. Narath stressed that the growth of laboratory partnerships with industry would be even more critical for helping to recruit competent staff in an era when nuclear weapons research was not a very attractive career choice. He also thought that many of the other reasons for supporting the S&T park, such as regional economic development, were powerful, although perhaps not sufficiently compelling at the political level. He agreed that strong political support would be required.

Dr. Hartley observed, in answer to a question, that Sandia has taken an active role in a national network of research organizations and is now developing activities to help raise the organization's profile in the country's research universities.

Marc Stanley, from the National Institute of Standards and Technology (NIST), remarked that NIST's Advanced Technology Program (ATP) has as part of its statute a set of criteria governing the participation of foreign-owned corporations. These criteria set out certain tests, which include national treatment and respect for intellectual property rights, while ensuring that first benefits and manufacturing from a patent accrues to the United States. He believed that adopting these criteria could help to defuse the foreign participation question for Sandia.

Dr. Narath noted that the issue was harder for Sandia. For example, the Intel CRADA raised questions in relation to the transfer of weapons technologies to Japanese companies. Given these considerations, the tests to be passed for foreign participation might be more stringent for Sandia than for the ATP.

Dr. Wessner commented that the ATP's criteria at least offered some transparency, which was often welcomed by foreigners and Americans alike, and that the ATP criteria could at least be used as a base, with precedent, for developing Sandia policy on foreign access. At the same time, given the security mission, both technical and policy considerations would suggest that a certain amount of flexibility be retained by Sandia's management.

Mr. Borrus observed that spin-on, that is, how foreign participation in the Sandia park might benefit the mission of Sandia labs, would also become an important criterion. Dr. Wessner added that specific commitments about jobs and economic benefits to the United States could also be included in the list of criteria. In fact, absent these benefits, a proposed partnership might be ill-advised. Another participant observed that even where there is a net benefit to the United States, the existence of benefits for foreign participants raised questions in connection with federally funded research. Mr. Stanley observed that linking the partnership directly to the labs' mission was critical for deflecting these types of criticisms.

Intellectual Property Protection

Another participant noted that very specific intellectual property protections would be required before small firms would partner with the labs, as they face the risk that larger firms would subsequently partner with the labs and would then reap the intellectual benefits of the small firm's partnership. She noted that just such a case occurred recently at Sandia, in which a small company had been followed in a research area by a much larger partnership with Intel.

Commenting on the issue of merit-based choices, Dr. Wessner noted that, although it was a worthy and perhaps critical objective to ensure that projects were merit based, the challenge is always to identify meritorious projects without the benefit of hindsight.

Mr. Jennings answered that, although "merit based" did not always mean "peer reviewed," the experience at DARPA supported an approach that left funding decisions to civil servants who generally are not connected to the political environment, and hence tend not to be influenced by nonmerit factors. In general, observers accept that the project selection process at DARPA was a fair one that was broadly insulated from politics. This perception was important when DARPA was under political attack.

Mr. Der Torossian said that, despite the delays imposed by the bureaucracy, partnerships with government remain important. However, the U.S. government's role should be to increase the global market share of U.S.-based products and services, just as foreign governments seek to aid their firms. One way to handle the issue of foreign participation might be for laboratories such as Sandia to share their technology with foreign corporations provided that the latter pay a licensing fee to compensate the American taxpayer for the costs of the completed research. U.S. firms would be exempt from that fee. The objective should be to create advanced technology jobs in manufacturing in the United States, even if that means Sandia staff leaving for more-remunerative positions in industry.

Dr. Richard Thayer pointed out that, in an important way, the idea of the

Sandia S&T Park emanates from Sandia's success over the past decade in reaching out to industry. Sandia has made an explicit effort to work closely with industry on technological R&D projects of mutual benefit to Sandia and the companies involved. Although there are risks in such endeavors, Dr. Thayer noted, R&D has inherent risks of failure, whether undertaken by a national laboratory alone or in concert with industry.

Dr. Hartley noted that, from his perspective, one of the tests of Sandia's success is the extent to which staff find challenging jobs beyond the lab. Ironically, one indicator of the success of Sandia's partnerships with industry and the Sandia S&T park would be the private sector luring Sandia employees away.

Summary

Charles W. Wessner
National Research Council

Dr. Wessner observed that while it would be a challenge to summarize this wide ranging discussion, several general points had emerged. For example, it was clear that Sandia's project would require close cooperation among multiple institutions at the federal, state, and local levels, in addition to the DOE. The discussion had also revealed that the S&T Park proposal incorporated a number of distinct objectives. Sandia, of course, has its own rationale which it sees as directly linked to the completion of its core missions. The laboratory is seeking an environment able to attract and retain capable staff at a time when the nuclear weapons mission is perhaps less compelling to young researchers than it once was. Secondly, Sandia's management believes that to successfully execute laboratory missions, they increasingly need to rely on "spin-on," that is, to acquire commercial technologies developed outside the laboratory. This is a significant point. Major areas such as materials modeling and simulation, advanced manufacturing and semiconductor processing technologies are evolving very rapidly. Michael Borrus underscored the importance of this rationale in his remarks, suggesting this explanation needs to be more fully articulated for the Washington policy community.

THE LINK TO THE SANDIA MISSION

Dr. Wessner also reminded the group of the importance of the observation by Robert Simon of Senator Bingaman's office that for the foreseeable future Sandia would continue to receive its share of the $4.5 billion earmarked for the maintenance of the weapons stockpile. This large public investment reflects the importance of the mission. The effective execution of the mission requires the best techniques, technologies and engineers available. Emphasizing the benefits of the S&T park for the Sandia laboratory's core mission is therefore essential to gain public understanding and support. This is in fact the best response to those who question the possibility of private gain from long-term public investments in Sandia's infrastructure and research program.

At the same time, the limited direct federal financial role should be emphasized. Today's discussion made it clear that Sandia's S&T park project is not directly dependent on federal funding. However, Dr. Wessner continued, it is also important to recognize that there are likely to be some indirect costs to taxpayers involved in using a federal lab and federally contracted employees to develop the project. These costs would have to be weighed against what appear to be multiple potential benefits, including the not inconsiderable benefit of maintaining the technological edge of Sandia's facilities and staff. We should also keep in mind that these costs are in any case related to the fixed costs associated with the laboratory's core missions.

MISSION EXPANSION?

Dr. Wessner suggested that concerns about "mission creep" may be overstated. The laboratories have to adopt themselves to the post-Cold War environment both in terms of new sources of technology and new national objectives. Simulated testing is one example. There are others. For example, at the beginning of the symposium, Dr. Kelly suggested a series of potentially valuable applications of laboratory capabilities in areas such as health, environmental remediation, and public safety. Fundamentally, as Dr. Kelly and Dr. Simon both suggested, the Sandia asset base is a unique resource which can help the nation meet evolving security challenges, contribute to the competitiveness of U.S. companies, and advance national welfare.

CRITERIA FOR SUCCESS

Concerning the criteria for success, and mechanisms for recognizing failure, as well as the corresponding need for intermediate metrics, Dr. Wessner said that it might be possible to turn to DARPA's experience for help in this area. It is important to recognize publicly, however, that metrics of success are hard to develop, partly because, as many speakers noted, S&T parks have long gestation periods. The Sandia management should note, from a planning perspective, the many references to S&T parks requiring patience and deep pockets.

One of the most provocative challenges raised in today's discussion is that, because of the long gestation period, the failure of this type of initiative may not be readily apparent. It would therefore probably be useful for the Sandia management to develop specific milestones. For example, a regular assessment of user involvement, user satisfaction, and returns to the laboratory would be useful.

Also, it would be desirable if park tenants included multiple sectors, multiple companies, and companies of different sizes (i.e., they should not all be Fortune 500 companies).

In following up this symposium, Dr. Wessner observed that the STEP Board's project on "Government–Industry Partnerships for the Development of New Technologies" hopes to look at the experience of foreign S&T parks and at manageable criteria for allowing foreign-owned companies to participate in federally funded research programs.

Given the growing importance of collaborative research conducted over the Internet, Dr. Wessner asked whether the S&T park should act as a node on the Internet for regional research activities. This could perhaps add value to projects at the S&T park. This prompted one participant to observe that although he agreed the park should be on the Internet, it was not yet simple or easy to access specialized research facilities, such as those at Sandia, over the Internet.

In conclusion, Dr. Wessner recalled that several speakers had called for increased discretion for program managers and for reduced bureaucracy. Although clearly desirable, substantial increases in managerial discretion might prove difficult to achieve in the current political climate. He supported the notion that some easily understood benchmark criteria might therefore be a good safeguard. Other U.S. partnership programs, such as ATP, might offer valuable lessons in this regard. Last, he noted that, although he had heard several participants observe that Sandia is new to the partnership process and is, in effect, feeling its way, this remains an observation, not an explanation. The political and policy environment in which Sandia operates is likely to remain unforgiving.

Dr. Wessner closed the proceedings by thanking the many participants from around the country, and, in particular, the Sandia management who, at their own initiative, had asked the Academy to organize this discussion of Sandia's plans for a S&T park.

IV

ANNEXES

Annex A

A Sandia White Paper: Sandia National Laboratories and the Sandia Science and Technology Park[44]

Sandia National Laboratories

The mission of Sandia National Laboratories (SNL), whose primary location is in Albuquerque, New Mexico, is contributing to the security of the United States through the Stockpile Stewardship Program (SSP), which ensures the safety and reliability of nuclear weapons. Sandia's mission is an evolving one that must be immediately responsive to new and emerging vulnerabilities and threats to the security of the United States. It is a mission that is more challenging in some respects than ever before in the laboratory's 50-year history. In addition, in today's environment of smaller government, Americans want their government to utilize private resources whenever possible and they want to see the benefits of federal research and development extended throughout the U.S. economy. Congress also has encouraged federal laboratories to partner with the private sector.

Recently, SNL joined the city of Albuquerque, other local and state entities, and many private organizations and residents in support of the Sandia Science and Technology Park (SSTP), which is planned for a large tract of land immediately adjacent to the laboratory's main facility in Albuquerque. The plans for the park call for a campus-like setting, initially spanning some 285 acres. Fortune 500 companies and entrepreneurs are considering sites in the SSTP, recognizing the value of being close neighbors with other high-technology firms and within easy reach of leading research institutions in the New Mexico Technology Corridor. Potential tenants will be located in the midst of one of the richest scientific research and engineering talent pools in the nation. The park will be served by a

[44] This paper was prepared by the Sandia National Laboratories at the request of the National Research Council to provide additional background information about the SSTP initiative.

high-speed, state-of-the-art communications infrastructure designed to facilitate collaboration within the park; with Sandia and other nearby facilities; and with business, research, and academic institutions nationally and internationally.

The Sandia Park is designed to enable close collaboration among global corporations, small start-up firms, universities, and other institutions. As great as the opportunities are for industry, close collaboration with the private sector is also of compelling importance to Sandia.

This paper first summarizes Sandia's challenging mission and then describes how partnering with leading high-technology corporations, innovative entrepreneurial companies, universities, and other research institutions will enable Sandia to accomplish its mission more effectively than it can in isolation. Sandia and the nation gain from partnerships that enlist private sector skills and resources to address national challenges. At the same time, partnering with Sandia benefits the companies involved and moves new technologies into the marketplace to the advantage of all Americans. The park will bring key institutions into close physical proximity and link them even more closely through advanced high-speed communications and will greatly facilitate collaboration and partnering.

THE EVOLVING MISSION OF SANDIA NATIONAL LABORATORIES

SNL is a multiprogram facility operated by the Sandia Corporation, a Lockheed Martin company, for the U.S. Department of Energy (DOE). Sandia's main location is in Albuquerque, New Mexico, with another important facility in Livermore, California. Sandia conducts broad-based research and development related to nuclear weapons, arms control, energy, the environment, and other areas of national need.

Sandia's principal mission is to support national defense policies, particularly the Stockpile Stewardship Program, by ensuring that the nation's nuclear weapons meet the highest safety, security, and reliability standards and that the SNL effectively accomplishes the nuclear deterrence policy of the United States. Sandia functions as the systems integrator for the DOE in managing the nuclear weapons stockpile and works also with the U.S. Department of Defense, other federal agencies, other laboratories, and industry to develop technologically superior military weapons.

A second aspect of Sandia's national security mission is to reduce U.S. vulnerability to proliferation, threat, or use of weapons of mass destruction, whether nuclear, biological, or chemical. Sandia develops effective responses to emerging threats by applying advanced technologies and systems solutions to problems such as terrorism, hard and deeply buried targets, chemical and biological weapons, information warfare, demining and unexploded ordnance neutralization, and demilitarization. Sandia also helps safeguard nuclear materials in other countries and designs effective systems to monitor nuclear weapons activities.

An additional responsibility of Sandia is to enhance the safety, security, and reliability of the nation's critical infrastructures and address energy and environmental threats and vulnerabilities and dangers to the nation's air and water supplies.

STEWARDSHIP

Historically, Sandia has been responsible for assuring the reliability of nuclear weapons, and, to that end, the lab has relied on world-class science and engineering. This task remains especially critical today, as the United States relies on existing weapons to protect itself and other nations, while fully supporting international agreements that ban nuclear testing and forbid the development of new nuclear weapons. As long as the United States has nuclear weapons, they must be kept secure and reliable.

The critical importance of the nuclear SSP was emphasized by Dr. Victor Reis, Assistant Secretary of Defense Programs at DOE, in recent testimony before Congress. His statement emphasized the importance of the SSP as the means by which the nation will assure the safety and reliability of its nuclear deterrent under a Comprehensive Test Ban Treaty. Dr. Reis also spoke of the need to maintain modern nuclear laboratory facilities, programs, and capabilities to provide the protection that the United States will require against any future hostile attacks. Noting specific efforts at Sandia and other nuclear weapons laboratories to measure up to the stockpile stewardship responsibility, Dr. Reis called the laboratories "the best in the world . . . better now than they were four years ago because of the enthusiasms and vigor with which they are attacking the stockpile stewardship effort."

NEW THREATS AND CHALLENGES

In spite of the end of the Cold War, nuclear, chemical, and biological weapons have proliferated in recent years among various nations and subnational groups, posing new threats to national security. Consequently, in addition to its nuclear weapons responsibility, Sandia must now also focus on new security threats, terrorism, disruption or sabotage of U.S. information systems, proliferation of weapons of mass destruction, and more. The United States must monitor possible weapons development activities, however well concealed, and determine how best to prevent harm in the United States and throughout the world.

There are other national needs to be addressed. Dependence on other nations for oil could jeopardize U.S. transportation systems if there were a disruption in the oil supply. Overconsumption of energy, in addition to depleting natural resources, could also seriously endanger our natural environment. Efforts to improve energy efficiency have thus become paramount. The federal government has turned to Sandia for help on all of these matters.

DRAWING ON THE RICH RESOURCES OF THE PRIVATE SECTOR

As national security and infrastructure needs have changed in recent years, there has been a dramatic change as well in the public's perception of the appropriate role for the federal government. Rather simplistically, a common view today appears to favor smaller government than has existed in the past, with greater reliance on the private sector to accomplish national goals.

TECHNOLOGY PARTNERSHIPS BETWEEN THE U.S. DEPARTMENTS OF ENERGY AND DEFENSE

Since the late 1980s, Congress has been taking specific steps to promote cooperation and partnerships between federal laboratories. Some of the policies that have been undertaken include

- the Stephenson–Wydler Act that lifted various restrictions and gave federal agencies the authority to participate with the private sector in technology transfer activities;
- the Bayh–Dole Act that provided specific intellectual property protections for small businesses and nonprofit organizations, primarily universities;
- the National Competitiveness Technology Transfer Act that gave government-owned, contractor-operated laboratories the authority to establish ownership of, protect, and license intellectual property;
- the 1996 Technology Transfer and Advancement Act, also known as the Morella Bill, that gave industry the right to negotiate with federal agencies and national laboratories for some form of exclusivity (field of use) in jointly developed intellectual property; and
- the 1993 DOE Defense Programs Technology Partnership Program that established a pool of funds to set up Cooperative Research and Development Agreements (CRADAs) for technologies developed jointly by a national laboratory and industry, with defense and commercial applications. The funding pool has varied greatly from a high of $250 million in FY 1995 to $60 million in FY 1998. Shortly after the funding became available, Sandia soon led all other national laboratories in total number and dollar value of partnerships with industry.

SANDIA'S MISSION IMPERATIVES

Like other federal facilities, Sandia has had budget reductions even as its mission has expanded. Not surprisingly and quite fortunately, Sandia has recognized that partnering with the private sector can leverage enormous resources across a broad spectrum of capabilities. Through hundreds of partnership agreements with industry over the past decade, Sandia has reached out to a rich reservoir of private sector technologies that has enabled the laboratory to more effectively meet its continually evolving missions. At the same time, these partnerships have proved valuable to the companies involved, helping them to solve problems that had previously appeared intractable. Partnering has become a valuable way to transfer technologies from defense to commercial applications, with benefits to industry, the economy, and the nation.

Some examples below highlight the benefits of Sandia's cooperation with the private sector.

Partnerships with Industry

High-Performance Computing

Many of the challenges engaging Sandia scientists and engineers require analysis of thousands of potential scenarios and many variables associated with each. In place of physical testing, today's research and engineering are rooted in modeling and simulation. The technology that has enabled this transition is high-performance computing.

Over the past decade, Sandia has been advancing high-performance computing capabilities and has become a world leader in massively parallel computing. In this approach, a problem is divided into segments, which are then solved by different parts of the computer simultaneously. This strategy has resulted in a tremendous increase in computing speed and power.

Partnering with industry has been fundamentally important to the development of high-performance computing at Sandia. In 1995 a team of researchers from Sandia and Intel combined two Paragon supercomputers at Intel's Beaverton, Oregon, facility to set a speed record in massively parallel computing. In 1996 Sandia and Intel broke the teraflops barrier, achieving one trillion calculations per second. The teraflops achievement represents a 1,000-fold increase in computing speed in less than a decade. The increased memory on the teraflops computer is as important as the increased speed. As the world's largest computer memory, it is greater by a factor of 15 than that of Sandia's Intel Paragon computer and greater by a factor of 1,000 than supercomputers developed a decade ago.

This greatly increased memory and speed, combined with new software and physical models, enables Sandia to solve a wide range of problems related to the safety and reliability of nuclear weapons and other weapons of mass destruction and problems across a broader range of national security concerns as well. These problems often involve the coupling of many complex physical effects in three dimensions. Examples range from virtual testing of weapons to predicting the effects of aging and assuring the reliability of stockpile materials. Aging studies are especially important because no new weapons are being produced, all underground testing has ceased, and older weapons must remain safe and reliable for many years beyond their original design life.

A new generation of superfast, high-performance computers is emerging, which will help provide the capabilities required to meet future national security demands.

Robotics and Intelligent Machines

Sandia is a leader in robotics and intelligent systems. These technologies are invaluable for performing difficult, repetitive, and monotonous tasks and, more importantly, tasks that would expose humans to dangerous environments and health hazards. Sandia has designed intelligent systems to dismantle nuclear weapons and explosive components and to remove hazardous materials to storage areas. Intelligent systems are also valuable for surveillance and monitoring of hostile environments under severe conditions and over long periods of time.

Partnerships with industry have extended the application of Sandia's intelligent systems technologies into previously unexplored areas, such as microsurgery and science-based aircraft maintenance, and, in general, have strengthened the laboratory's leadership in intelligent systems technologies, an area that is rapidly growing in importance, militarily and commercially. In partnership with automobile manufacturers, Sandia engineers are perfecting the surprisingly intricate and difficult task of transmission assembly; with an eye surgeon, Sandia is helping to develop delicate sensors that will eliminate the effects of microtremors from a surgeon's hands during an operation. By sharing and further developing its own expertise in these areas, Sandia is better able to meet its own critical mission requirements.

Relying on a half-century of experience in meeting the daunting tasks of designing, engineering, and dismantling nuclear weapons, and for many years developing systems to clean up and store radioactive waste, the federal government has sought Sandia's assistance in its investigation of crises such as the bombing of the World Trade Center in New York City and the 1995 destruction of the federal building in Oklahoma City.

Microelectromechanical Machines

Microelectromechanical systems are minute devices, some as small as the diameter of a human hair, with features as small as 1/100 the diameter of a hair, that combine mechanical and electrical components in a single system. These devices are useful for a variety of military and commercial applications, including safety locks for nuclear weapons. Sandia's leadership position in this technology must be attributed, in an important way, to collaboration in microelectronics with IBM. In addition to working closely with Sandia on microelectronics technologies over a number of years, IBM also made a major contribution of equipment to Sandia's microelectronics laboratory.

The Goodyear Experience

Goodyear is the only remaining U.S.-owned global tire company. According to Goodyear, its partnership with Sandia has produced the most advanced tire technologies in the world. The same technologies have enabled Goodyear to achieve continued success in the global marketplace. The partnership began in 1993, focusing on computational mechanics and advanced materials. These areas were important to Sandia because of its work on nuclear weapons; Goodyear was interested because it needed to improve the quality and performance of its tires. Although not obvious at first, the Sandia–Goodyear partnership has demonstrated that there are areas of significant technology overlap in these very different missions and therefore there is a common interest in working together. The ongoing partnership has proved mutually beneficial, enabling both Sandia and Goodyear to accomplish their missions more effectively.

Other examples of technologies pioneered at Sandia that have had important benefits for U.S. industry include the laminar air flow clean room, which is now an essential requirement in virtually every microelectronics manufacturing facility; vertical cavity surface-emitting lasers, which are poised to revolutionize laser communications from fiber-optic telecommunications transmission to office copying machines and cellular telephones; and advanced lithography research, which has established important new milestones in integrated circuit manufacturing.

Advantages of Partnerships

Partnering with industry has helped Sandia to advance its skills and technologies in many areas; the examples given above illustrate the importance of such partnerships in enabling Sandia to more effectively and efficiently accomplish its national security missions. As Sandia looks to the future, with an expanded mission, reduced federal budgets, and rapidly advancing costly technologies, private sector resources must be drawn upon to complement those of the laboratory itself.

Businesses that work with Sandia find world-class facilities and expertise and a businesslike culture derived from more than 50 years of management by two of the nation's leading corporations, AT&T and Lockheed Martin. In addition to the areas mentioned above, Sandia's advanced manufacturing facility and its microelectronics laboratory have been particularly attractive to industry.

The rich reservoir of advanced technology and the vast range of knowledge, expertise, and skills at Sandia have been built up over more than half a century with considerable investment by U.S. taxpayers. Although Sandia's technology and skill base have been funded by the government for critical national security purposes, it would be a significant loss to the nation to ignore the far-reaching economic and social benefits that can derive from these resources. Sandia's efforts to partner with industry is one means of assuring that these economic and social benefits are attained.

A PLAN FOR MORE-EFFECTIVE PARTNERING: THE SANDIA SCIENCE AND TECHNOLOGY PARK

Partnering with industry is increasingly necessary for Sandia to accomplish its expanding mission. Such partnerships benefit industry and the U.S. economy as well, bringing defense-related technologies to valuable commercial applications in the private sector. The Sandia Science and Technology Park creates a new research and technology community where opportunities for productive cooperation can develop and flourish.

Although the institutions and history of Albuquerque are unique, the idea for a community of laboratories, high-technology corporations, innovative entrepreneurs, universities, and other research institutions is not new. Similar efforts in other parts of the United States have achieved remarkable success. Examples such as the Research Triangle Park in North Carolina, the Silicon Valley Incubator in California, and the Ben Franklin Technology Centers in Pennsylvania underscore the diverse conditions in which the partnership concept has been applied. These facilities are home to many of the country's leading high-technology corporations. They have facilitated extraordinary research and technology achievements across a broad range of areas, with widespread benefits.

The Sandia Science and Technology Park in Albuquerque can make its own unique contribution. The plan is singularly creative, representing the first research and technology facility with a leading national laboratory as its hub. The SSTP will bring together interested public and private parties at the local, state, and national levels. It will include world-class high-technology research and manufacturing firms, leading telecommunications and information technology companies, and creative start-up firms. The park's potential is widely recognized, as evidenced by the support of major financial institutions. The SSTP will also benefit from first-rate local and national transportation facilities and state-of-the-art communications.

The goal of SSTP is to build a rich and diverse community of highly productive organizations, together with talented people and advanced technology. The people, corporations, and other organizations that occupy the park will create a cluster of technology resources adjacent to Sandia and will be made up of major companies, other laboratories, universities, and a highly skilled work force.

The park will be anchored by Sandia National Laboratories, with its world-class stature, and buttressed by other excellent research institutions, which, collectively, invest about $4 billion in research and development annually. These institutions and a technically adept population will create a critical mass of scientific and technical expertise in a setting highly conducive to partnering. Federal, state, and local officials have expressed their unqualified support for the SSTP, and the DOE has already committed $250,000 to the city of Albuquerque to help fund basic infrastructure construction for the park.

What distinguishes Sandia is its dedication to science with the end in mind, a process essential for the laboratory to meet its national security responsibilities. These responsibilities require performance backed by broad-based scientific knowledge, agility, and expertise. To achieve this, Sandia brings together the best qualified scientists and engineers to meet the challenges at hand. More and more, this means working with partners in industry, academia, and other federal laboratories. The establishment of the Sandia Science and Technology Park is an important step in creating such partnerships.

Annex B

Overheads on the Research Triangle Experience

Prof Michael Luger

THE ROLE OF S&T PARKS:

The Research Triangle Experience

with Lessons for Sandia

Presentation at NRC Symposium on
Industry-Laboratory Partnerships:
The Role of S&T Parks

April 22, 1998

Prof Michael Luger
University of North Carolina at Chapel Hill

Outline of presentation

I. Basis for remarks

II. Overview of S&T (research) parks in the US

III. What makes them "successful?"

IV. The RTP phenomenon

V. The rest of the world—further lessons

Basis for remarks

- 1991 book on US parks, including case study of RTP
- Subsequent work on S&T parks and S&T policy in US, Europe, and Asia
- Subsequent work on the role of universities and research centers/labs in regional economic development
- Economic studies of Research Triangle; most recently, *At the Crossroads: North Carolina's Place in the Knowledge Economy of the 21st Century*

Overview of S&T (research) parks in the US

Type of park	# of parks	Median Age, 1995	Mean # tenants, 1989	Mean # tenants, 1995
Fast growing	17	16	32	58
Growing	30	11	3	19
Stagnant	12	12	34	41
Declining	3	14	33	35
Early parks, no data	13	12.5	8	
Later parks, no data	28	13	35	
Newcomers	41	5	8	
No longer park	4		10	
Not located	16	12	18	
Skipped in 1989	20	11		
TOTAL	184			

Overview of S&T (research) parks in the US

Type of park	% in NE and MA	% in S	% in W and NW	% with access to university	% with infra-structure
Fast growing	42	29	12	88	76
Growing	10	30	24	80	80
Stagnant	25	33	33	58	33
Declining		67		67	33
Early parks, no data	30	38	15	77	62
Later parks, no data	18	25	21		
Newcomers	35	34	9	66	59
No longer park	25	25	25		
Not located	27	40	13		
Skipped in 1989	44	17	22		

Overview of S&T (research) parks in the US

Specializations of different types of parks:

- **Fast growing**
  - telecommunications
  - optics, lasers
  - medical equipment
  - biotech
  - software
  - chemical
- **Newcomers (>1988)**
  - medical research
  - biomedical
  - information technology
  - software
  - environmental
  - health/medical/ pharmaceutical
  - semiconductor/advanced materials

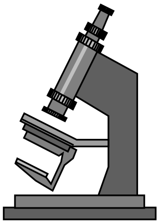
What makes parks "successful?"

- "Success" is a normative concept; can be defined in several ways:
  - as a real estate project
  - in terms of "policy effectiveness" (outcomes vs. goals)
  - in terms of efficiency (is present value of net benefits >0?)
  - in terms of ability to transform a regional economy (longer time horizon)

What makes parks "successful?"

The U.S. story, in brief

Our 1991 study used *net induced job creation in the region* as measure of success; outcomes varied among parks



Research Park Success Indicators

NAME OF PARK	LOCATION	YEAR ESTABLISHED	DIFFERENCE (%)
Ada Research Park	Ada, OK	1960	-0.02
Ann Arbor Technology Park	Ann Arbor, MI	1983	-1.49
Arizona State University Research Park	Tempe, AZ	1984	-0.17
Carolina Research Park	Columbia, SC	1983	-0.16
Central Florida Research Park	Orlando, FL	1979	0.72
Charleston Research Park	Charleston, SC	1984	-1.20
Chicago Technology Park	Chicago, IL	1984	1.65
Clemson Research Park	Clemson, SC	1984	0.38
Connecticut Technology Park	Storrs, CT	1982	3.18
Cornell Research Park	Ithaca, NY	1951	9.48
Cummings Research Park	Huntsville, AL	1962	0.40
Engineering Research Center	Fayetteville, AR	1980	0.02
Great Valley Corporate Center	Malvern, PA	1974	0.08
Innovation Center and Research Park	Athens, OH	1978	1.94
Interstate Business Park	Tampa, FL	1983	-1.05
Johns Hopkins University Research Park	Baltimore, MD	1984	-0.64
Langley Research & Development Park	Newport News, VA	1966	-8.80
Maryland Science and Technology Center	Adelphi, MD	1982	1.44
Massachusetts Biotechnology Research Park	Worcester, MA	1984	3.48
Miami Valley Research Park	Kettering, OH	1981	0.11
Morgantown Industrial & Research Park	Morgantown, WV	1973	0.24

RTP DIFFERENCE is 4.45; DIFFERENCE is employment growth in park region minus employment growth in control counties after park opens.

What makes parks "successful?"

Regression analysis of 70 parks (DIFF on explanatory variables and a hazards model), and case studies of 3 parks (RTP, Stanford, Utah) indicated the following common success factors:

- parks had marketing and development strategy appropriate for region's resources and culture
- parks provided services/infrastructure consistent with tenants' needs
- park businesses and nearby university connected in meaningful ways
- there was visionary leadership and cooperation
- there were deep pockets and patience
- there was good timing and good luck

Δ The Research Triangle phenomenon

- The region in 1959/early 1960s
  - — traditional, low wage manufacturing
  - — universities were regional
  - — severe brain drain as a consequence
  - — strategic location at doorstep of "new south"
  - — large tracts of centrally located land
  - — enlightened leaders from government and business: Sanford, Hodges, Guess

Δ The Research Triangle phenomenon

- Strategic decisions in park development
  - — get government anchors
  - — get blue chip corporate anchor; branch plant location as regional HQ
  - — sell land with covenants
  - — provide high level of services
  - — make sure universities have meaningful input in governance

RTP has used relatively little government assistance

Δ The Research Triangle phenomenon

One out of 4 jobs created in the region between 1959-1990 traced to park (almost 60,000). INCLUDES:

- — jobs in park businesses (>30K, many would not have been there otherwise)
- — jobs created via spending multiplier from induced jobs in the park
- — jobs created in businesses that provide goods and services to induced businesses in the park
- — jobs in companies spun off from park businesses, and through that multiplier

We did not count jobs in businesses that moved to region not to be in park, but because of reputation of region, due to park

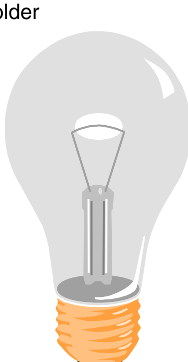
Δ The Research Triangle phenomenon

- The region in 1998
  - — high tech employment in universities, labs, hospitals gives region one of highest ratios of Ph.D.s per capita
  - — three research universities are nationally ranked
  - — brain drain is now brain draw
  - — considerable volume of spin-off activity from industry and universities
  - — region is fast growing; 1.2 million population

Spin-offs

Recent research identified a total of 32 high-technology spin-offs from North Carolina universities between 1972 and 1997. Sixteen of those taken place since 1991, implying a considerable increase in spin-off activity in recent years, though trend is difficult to assess since older spin-offs are more difficult to identify. Unsurprisingly, the state's three largest research universities, UNC-CH, Duke , and NCSU, generated almost all the spin-offs, and most were located in the Research Triangle area.

Spin-off/start-up activity from industry comes from high-level scientists and engineers let go in restructuring… having severance, pensions, savings, and real estate to use as seed capital



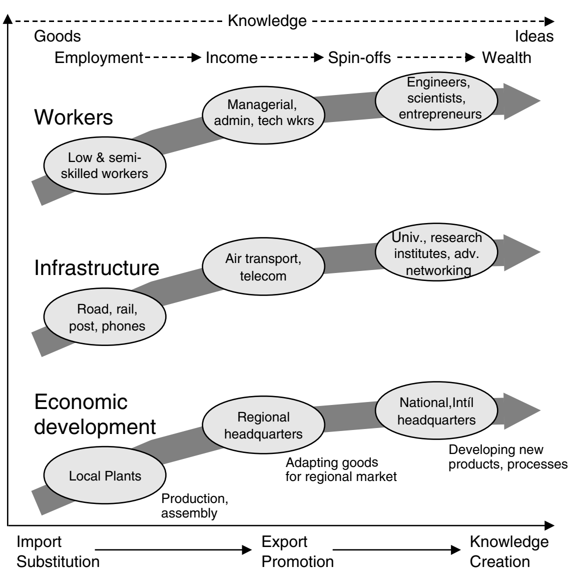
S&T parks worldwide

Sample of S&T parks elsewhere:

- South Africa (4)
- China (8)
- Japan (7)
- Thailand (2)
- Russia (11)
- Canada (18)
- Finland (10)
- France (53)
- Italy (11)
- United Kingdom (44)
- Australia (15)
- Brazil (3)

These countries differ widely in their levels of economic development

Principles:
Knowledge Along the Economic Development Continuum



Policy: Services Along the Economic Development Continuum

Improving production techniques and inputs →	Conducting applied research →	Commercializing outputs of basic & applied research →	Conducting basic & applied research
Provide worker training	Provide technical training	Provide licensing and patenting assistance	Provide/operate specialized equipment and facilities
Provide managerial training	Provide/operate testing and calibration equip.	Provide incubator space	Provide a good work environment
Offer technical assistance to help solve problems	Help organizations link to local universities/institutes	Help organizations obtain financing for start-up or expansion	Help organizations connect to appropriate global knowledge resources
Build/operate a pilot plant	Provide crunch space	Provide marketing assistance	
Help establish buyer-supplier networks		Provide entrepreneurial training	

Lower level of economic development - - - - - - - - - - - - - - - - ▶ Higher level of economic development

Lessons for Sandia

- — With proliferation of parks, it may be difficult to achieve success in conventional terms
- — Park may help establish region as growth pole, substituting for urbanization economies
- — Planners need to heed lessons from successes:

— parks had marketing and development strategy appropriate for region's resources and culture

— parks provided services/infrastructure consistent with tenants' needs

— there was visionary leadership and cooperation

— there were deep pockets and patience

— there was good timing and good luck

Annex C

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Annex D

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