PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY • JUNE 2004

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Federal-State R&D Cooperation

Improving the Likelihood of Success

About the President’s Council of Advisors on Science and Technology

President Bush established the President's Council of Advisors on Science and Technology (PCAST) by Executive Order 13226 in September 2001. Under this Executive Order, PCAST “shall advise the President ... on matters involving science and technology policy,” and “shall assist the National Science and Technology Council (NSTC) in securing private sector involvement in its activities.” The NSTC is a cabinet-level council that coordinates interagency research and development activities and science and technology policy making processes across federal departments and agencies.

PCAST enables the President to receive advice from the private sector, including the academic community, on important issues relative to technology, scientific research, math and science education, and other topics of national concern. The PCAST-NSTC link provides a mechanism to enable the public-private exchange of ideas that inform the federal science and technology policy making processes.

PCAST follows a tradition of Presidential advisory panels on science and technology dating back to Presidents Eisenhower and Truman. The Council’s 23 members, appointed by the President, are drawn from industry, education, and research institutions, and other nongovernmental organizations. In addition, the Director of the Office of Science and Technology Policy serves as PCAST’s Co-Chair.

Acknowledgements

PCAST would like to thank a number of Ohio-based science and technology (S&T) experts who played a special role in assisting PCAST in organizing this workshop; these include Frank Samuel and John Dudley with the Ohio Governor’s office, and Dorothy Baunach and Arlene Castaneda of Nortech.

Federal-State R&D Cooperation:

Improving the Likelihood of Success

Summary of a Workshop convened by the
President's Council of Advisors on Science and Technology
June 29, 2004
Cleveland, Ohio

Preface

The President's Council of Advisors on Science and Technology (PCAST) has considered the various elements, participants, and stakeholders in what it calls the Nation's "innovation ecosystem." Technological innovation is hailed by many as the engine of the U.S. economy and is closely related to broad U.S. leadership in scientific and engineering research and education during the past half century. Past reports of the Council on this topic include Sustaining the Nation's Innovation Ecosystems: Information Technology Manufacturing and Competitiveness, issued in January 2004, and Sustaining the Nation's Innovation Ecosystems: Maintaining the Strength of Our Science and Engineering Capabilities, which was released in June 2004.

As it studied the innovation ecosystem, PCAST became aware of the growing role State and local organizations play not only in high tech economic development, but also in supporting research and development and in the transfer of research results to commercial use and public benefit. Economic powerhouses like Silicon Valley and Boston's Route 128 have prompted other communities to take steps to provide supportive environments and to promote partnering among local stakeholders, including research institutions, businesses, and investors. Federal funding for research and development is a key ingredient in such efforts, but increasingly, States are supplementing the Federal investment with additional resources for activities ranging from research to technology transfer to growing jobs and businesses.

In order to understand current issues and to highlight successful examples and best practices of State high-tech economic development, PCAST held a workshop on Federal-State R&D Cooperation: Improving the Likelihood of Success in Cleveland, Ohio on June 29, 2004. The workshop focused on interactions among governments, academia, and industry and also heard presentations by representatives from several successful State S&T initiatives. Two panels focused on specific industries important in the Cleveland area—aerospace, a long standing yet evolving sector, and biotechnology, an emerging strength of the region. This report summarizes the material presented at the workshop.

The workshop gave PCAST deeper understanding and increased appreciation of the role the States play in our complex innovation ecosystem. The ongoing health of this ecosystem will depend on sustaining all of its components and the connections among them.

John H. Marburger, III
Co-Chair

E. Floyd Kvamme
Co-Chair

President's Council of Advisors on Science and Technology

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Executive Summary

> *"America's economic vitality comes from our ability to introduce a steady stream of high value-added products into the marketplace....Where do these products come from? How do we make sure they keep coming?"*
>
> John H. Marburger III, PCAST Co-Chair

What roles do States play in the national innovation ecosystem? On June 29, 2004, the President's Council of Advisors on Science and Technology (PCAST) convened a one-day workshop in Cleveland, Ohio on the topic of Federal-State R&D Cooperation for Technology Development: Improving the Likelihood of Success. The goals of the workshop were to identify "best practices" and to spotlight opportunities for collaboration at the intersection of Federal, State, academic, and industrial investments in innovation and technology development. This report arranges the workshop findings along five broad principles for successful regional innovation:

- Build competencies with attention to regional strengths.
- Identify a research strategy.
- Build a regional environment.
- Form regional partnerships.
- Fund the innovation machinery.

The Federal Government has an inherent interest in promoting innovation based on regional strengths. Competency building requires those involved in economic development to identify and build on existing regional strengths, including resources, institutions, and talent pools. Regional planning strategies often must overcome challenges, such as reorienting research universities to address economic innovation.

Successful research strategies exploit regional strengths while enabling partners to take advantage of new opportunities as they arise. A strategy should establish research priorities, allocate institutional resources to priority projects, and invest in personnel development and capital improvements. Local institutions and organizations must agree on the broad research and development (R&D) themes and on how best to use these themes to direct regional economic development goals. Many regions develop "innovation portfolios" that feature a mix of R&D functions across regional sectors, possibly employing a technological "push-pull" strategy. Regions also encourage firms to retool to provide products and services of higher added value. On a smaller scale, city-wide collaborations partner major institutions for similar results.

The Federal Government, the States, universities, and local industry all play key roles in fostering robust regional innovation environments. Successful environments feature strong intellectual and physical infrastructures, opportunity for knowledge crossover, a technically skilled workforce, sufficient capital, an entrepreneurial culture, and good quality of life. Regional partners must discuss and agree upon the research strategy, and technology transfer legislation—such as the Bayh-Dole and Stevenson-Wydler Acts—is essential for successful regional innovation. Even so, many States still do not recognize the value of long-term investment in science and technology (S&T) and do not adequately address funding inefficiencies.

Regional partnerships bring the Federal Government, State governments, universities, and industry together to pursue common regional goals. Although each member has its own objectives, partnerships discourage institutional rivalries and foster collaboration. The primary challenge is to find common incentives.

Experience has shown that partnerships are most successful when the appropriate partner takes the lead, the goal is clearly stated, and all involved parties consult with each other extensively. However, improved strategies for innovation-based regional economic development still are needed.

Finally, investment must be made in the facilities, people, and organizations that are critical to technology transfer and regional development. Investment is needed especially for those activities that produce products of high added value. The Federal Government acts as both a customer for, and a partner with, industry. Therefore, it has a vested interest in supporting strategies that promote regional innovation—especially for ventures that compete against heavily subsidized foreign competitors. Federal support can take the form of educational leadership, venture capital, and more focused support by the Small Business Administration.

PCAST is encouraged by the many “success stories” that were presented during the workshop. Members are hopeful that Federal and State governments will continue to develop and pursue creative ways to support innovation, including through collaborative investment in S&T and technology transfer. Such collaboration will stimulate economic growth and help to sustain our Nation’s position as a technology leader.

WORKSHOP ON FEDERAL-STATE R&D COOPERATION

Improving the Likelihood of Success

Inter-Continental Hotel
Cleveland, Ohio

June 29, 2004

AGENDA

Welcome and Introductions
8:45 – 9:30 a.m.

The Honorable E. Floyd Kvamme, PCAST Co-Chair
Partner, Kleiner Perkins Caufield & Byers

The Honorable Bob Taft
Governor of the State of Ohio

Opening Remarks
9:30 – 9:45 a.m.

The Honorable John H. Marburger, III, PCAST Co-Chair
Director, Office of Science and Technology Policy, Executive Office of the President

Panel 1 - The Government/University/Industry Intersection: Elements of Success
9:45 – 11:05 a.m.

Carl Kohrt, Moderator
President and CEO, Battelle

Edward W. (Ned) Hill, Panelist
Professor in Urban Studies and Public Administration, Cleveland State University

Dan Berglund, Panelist
President and CEO, State Science and Technology Institute

Sean Murdock, Panelist
Executive Director, NanoBusiness Alliance; Founder, AtomWorks

Panel 2 - Effective State S&T Strategies
11:10 a.m. – 12:30 p.m.

Thomas A. Waltermire, Moderator
CEO, PolyOne Corporation

Leslie Hudson, Panelist
Vice Provost, Office of Strategic Initiatives, University of Pennsylvania

C. Michael Cassidy, Panelist
President, Georgia Research Alliance

Sheri Stickley, Panelist
Director, Technology Development, Oklahoma Center for the Advancement of Science and Technology

Lunch Break
12:30 p.m. – 1:15 p.m.

Panel 3 - Aerospace: A Case Study of Sustaining a Mature Sector
1:25 – 2:45 p.m.

Peter V. Buca, Moderator
Branch Technology Director, Parker Hannifin Corp.

Michael Benzakein, Panelist
General Manager, Advanced Technology & Military Engineering, GE Aircraft Engines

James Williams, Panelist
Dean, College of Engineering, The Ohio State University

Thomas Cruse, Panelist
Chief Technologist, Wright Patterson Air Force Research Lab

Panel 4: Biotechnology: A Case Study of Emerging Sector Development
2:50 – 4:25 p.m.

Kathie L. Olsen, Moderator
Associate Director for Science, OSTP

Rich Christiansen, Panelist
Deputy Director, NASA-Glenn Research Center

Gil Van Bokkelen, Panelist
Chairman, President and CEO, Athersys, Inc.

Joseph Hahn, Panelist
Chairman, CCF Innovations, Cleveland Clinic Foundation

Ralph I. Horwitz, Panelist
Dean, Case School of Medicine, and Director, Case Research Institute,
Case Western Reserve University

Meeting Overview and Wrap-Up Discussion
4:30 p.m.

Luis Proenza, Co-Moderator
PCAST Member

Bernadine Healy, Co-Moderator
PCAST Member

Adjournment
5:00 p.m.

Introduction and Background

> *"Earlier this year, PCAST completed a report on information technology manufacturing and competitiveness. . . . In that report, we learned that there was a tremendous interest in the Federal Government's role in developing the innovative processes that lead to manufacturing and competitiveness. But we also found that the role of the States was also very critical to the many companies we interviewed . . ."*
>
> E. Floyd Kvamme, PCAST Co-Chair

The successful conception, design, and production of technologically intensive products require a vast scientific infrastructure, the scale of which extends well beyond anything that a single organization can provide. The private sector and the Federal Government are traditionally recognized as playing primary roles in innovation on this scale. The unique contributions of State governments are less well recognized. As a result, the role of States in the national innovation ecosystem has not been as closely studied.

In June 2004, the President's Council of Advisors on Science and Technology (PCAST) organized a workshop in Cleveland, Ohio to focus attention on the contemporary strategies of States and regions to achieve economic competitiveness through partnerships with the Federal Government and other institutions. PCAST was fortunate to be able to draw upon the experiences and insights of experts from around the country, many of whom participated in person at the Cleveland venue, in organizing the workshop. The decision to convene this meeting in Cleveland also made it possible to involve key State and local officials in our discussions, including the Governor of Ohio, Bob Taft.

John H. Marburger III, Director of the Office of Science and Technology Policy in the Executive Office of the President and the PCAST Co-Chair, opened the workshop by offering his observations of regional technology-based economic development, drawing from his experience first as a graduate student at Stanford University, then as a faculty member at the University of Southern California, and later as president of the State University of New York at Stony Brook and Director of the Brookhaven National Laboratory. Dr. Marburger distilled five principles for establishing strong and effective links among universities, regional businesses, and governmental economic development agencies:

1. Build competencies with attention to regional strengths: consciously build and focus on regional strengths, not just institutional strengths.
2. Identify a research strategy: establish research priorities, allocate institutional resources to project development in priority areas, and invest in personnel development and capital improvements to achieve research goals.
3. Build a regional environment: discuss the research strategy with all potential partners, including local business groups, chambers of commerce, State and local government agencies, and academic institutions.
4. Form regional partnerships: discourage counterproductive institutional rivalries and foster the cooperation and collaboration that are essential for regional-scale development.
5. Fund the innovation machinery: invest in the facilities, people, and organizations that are critical to technology transfer and regional development, especially those that are used for high "value added" products, which require large capital investments.

The following summary of the workshop proceedings adopts these five principles of regional development as organizing themes. Specific observations by PCAST members and panelist responses to key questions have been synthesized to highlight the five areas. This report also includes, as Appendices, four information briefs that were provided as background to PCAST in advance of the workshop. The briefs focus on: innovation systems, States and innovation, clusters for economic development, and State funding of S&T-based economic development.

A complete transcript of the proceedings and copies of panelist presentations can be found at http://www.ostp.gov/pcast.

In Ohio, we have been working hard to build new creative partnerships among research centers and between research institutions and Ohio businesses. Our goals are to expand our R&D sector, attract more Federal research funding, and grow new companies and good jobs through innovation and the introduction of new technologies. For example, an $8 million grant from the State brought together the Cleveland Clinic, Case Western, and University Hospitals to form BioEnterprise, which is supporting the growth of new business companies based on the world-class research going on here in Cleveland. Two-and-a-half years ago, we launched the State's Third Frontier Project, to build on Ohio strengths in growing sectors of the economy, information technology, advanced materials and manufacturing, power and propulsion, instruments, controls, and electronics, and bioscience and biotechnology. We are investing in areas of applied research, technology development, and early-stage capital formation to use new knowledge to create new products, new businesses, new companies, and new jobs.

Ohio Governor Bob Taft

PCAST Workshop on Federal-State R&D Cooperation

June 29, 2004

Building Competencies with Attention to Regional Strengths

"...No company is an island. This is the time for cooperation."

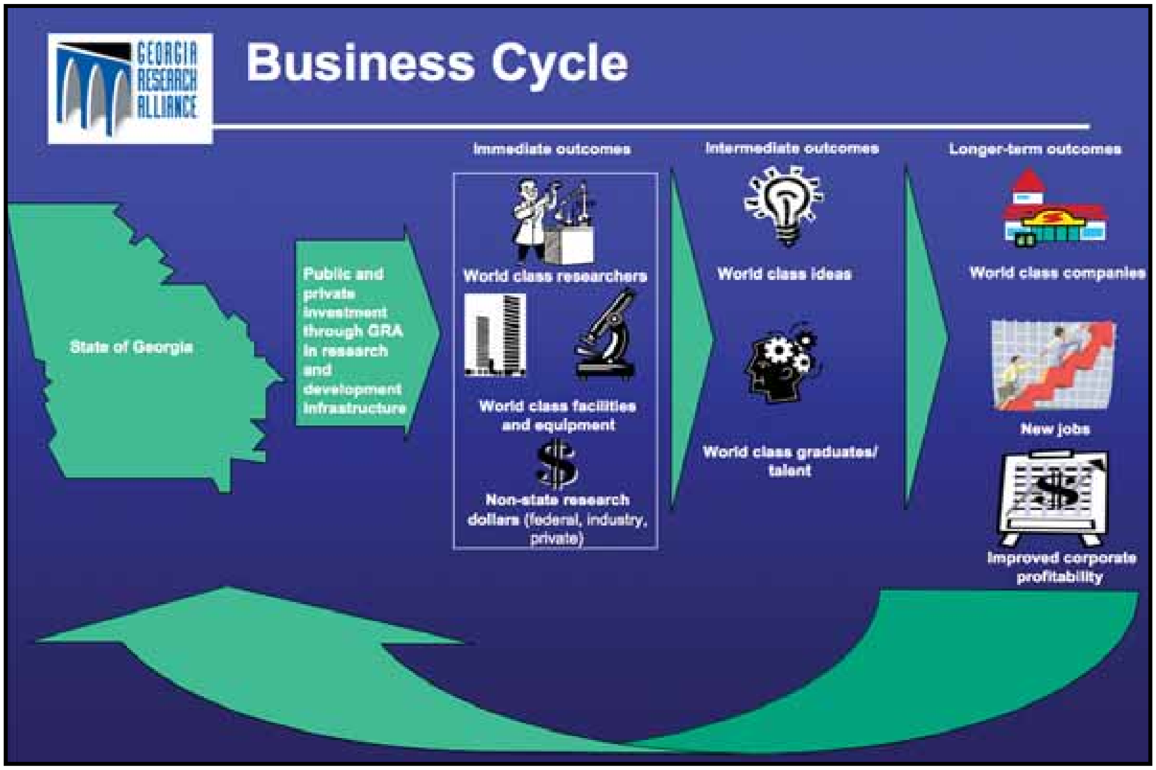
Carl Kohrt, President and CEO, Battelle

While the United States of America comprises 50 States and many Territories, planners and policymakers often devise economic development strategies that build on the resources within a region. Some regions may be located within a State, while others represent cooperative efforts across States. Regardless of the approach, regional planning builds upon the unique resources, institutions and talent pools in a geographic area for purposes of developing effective economic development strategies to enhance local, State, regional, national, and global competitiveness.

The State of Georgia, for example, has built a technology development plan around the traditional strengths of its universities. A key component of this plan involves the Georgia Research Alliance, which connects business, university and government leaders to, in the words of C. Michael Cassidy, President of the Georgia Research Alliance, "generate start-ups, attract industry, enhance jobs, and create wealth." The cornerstone of their effort is the "Eminent Scholars Program," which recruits some of the best and brightest researchers into the State and then builds linkages and networks around it.

The introduction of new regional planning strategies, however, is not without its stumbling blocks. The initial challenge for Georgia, according to Dr. Cassidy, was to orient the State's research universities that were not used to regional economic development to such innovation strategies as "targeting," "concentration" and "collaboration" (see Figure 1 and Appendix A) to make Georgia a knowledge-driven enterprise.

[1] The roles of States and regions are examined more fully in the "Information Briefs" included at the end of this report.

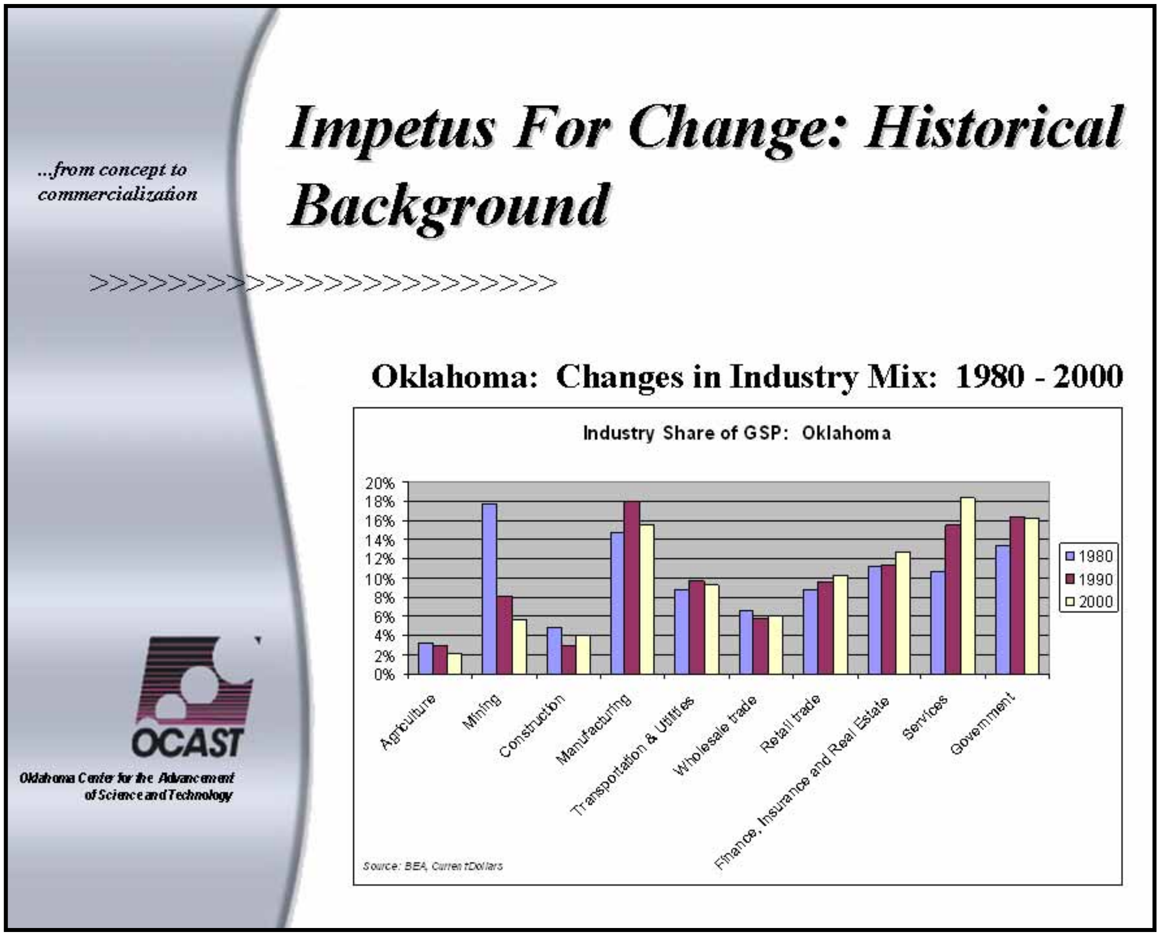


Source: C. Michael Cassidy, GRA

Figure 1: The business cycle as characterized by the Georgia Research Alliance.

As a result of Statewide adoption of the new strategy, Georgia has attracted over 100 world class scholars and researchers, created 750 high-tech research jobs at Georgia's research universities, and assisted in the formation of 80 companies and over 2,000 new high-tech jobs since 1990.

The State of Oklahoma provides another interesting example of an innovative S&T-based economic strategy built on regional strengths. Following a series of setbacks in the 1980s, the State of Oklahoma in 1987 established the Oklahoma Center for the Advancement of Science and Technology (OCAST) to foster innovation in businesses through basic and applied research, as well as through the facilitation of technology transfer (see Figure 2). Today, Oklahoma's "industry clusters" focus on life sciences, telecommunications, weather-related industries, and aerospace. According to Sherilyn S. Stickley, OCAST Director of Technology Development, the regional cluster approach has enabled Oklahoma to promote economic diversification, especially by fostering enhanced competitiveness of small- and medium-sized manufacturing firms.



Source: Sherilyn S. Stickley, OCAST

Figure 2: Changes in industrial mix in the State of Oklahoma, 1980-2000.

The Federal Government also takes an interest in promoting innovation on the basis of regional strengths. Rich Christiansen, Deputy Director of NASA's Glenn Research Center, reviewed the arrangements that center directors will consider to enable centers to accomplish their missions. Christiansen noted that NASA center directors are traditionally given wide latitude for determining these arrangements. Over the past few years, the NASA Glenn Research Center has established Joint Sponsored Research Agreements with university and industrial partners to take advantage of what Christiansen terms the "wealth of resources all around us." Together with other available mechanisms, such agreements aim to promote the propagation and use of NASA-formulated technologies through interaction with local, State and regional partners.

Identifying a Research Strategy

"…States throughout the country are struggling with many of the same issues."

Thomas A. Waltermire, CEO, PolyOne Corporation

The first step in developing a State or regional research strategy is to bring together local institutions and organizations to agree upon broad research and development (R&D) themes, as well as to agree on how best to use these themes to direct regional economic development goals.

Since few regions have the capacity to promote innovation through the support of "high risk" research, many regions develop "innovation portfolios." An innovation portfolio involves a mix of R&D functions across sectors of the region, and might include a technology-based "push and pull" strategy that could be implemented by companies in the region's industrial base.

In addition to developing innovation portfolios, regions frequently encourage firms providing products and services of low added value to retool so that they can eventually provide products and services of higher added value. According to panelist Edward W. (Ned) Hill, Professor in Urban Studies and Public Administration at Cleveland State University, the core of a region's strength should be firms that develop products of high added value on the basis of their contributions to State, regional and often national economic development.

Professor Hill divides State and regional firms into five categories:[2]

1. Product innovators manage continuous product innovation, own intellectual property, and have proprietary knowledge. This category is the "brass ring" of the American economy; constituent firms achieve profitability through innovation and by maintaining their cost structures.
2. Process innovators and global competitors chiefly ride product catalogues and use information technology to tighten their supply, customer, and value chains. They develop global supply chains and remain profitable over the medium- to long-term.
3. Lifestyle companies, which form the bulk of U.S. firms, seek retention of owner control and the earning of targeted income rather than growth. They are not profit maximizers, frequently have no intellectual property or proprietary competitive advantage, and have the choice of either moving up or down the typology.
4. Commodity businesses are "one-trick ponies" that are dependent on a single business or production relationship. When they lose that relationship, they become dead or dying companies.
5. Dead or dying companies enter job shops in auction markets.

According to Professor Hill, the policy challenge lies in transforming type 3 and type 4 companies into type 1 and type 2 companies. The transformation does not require changes to the technological base of a region; rather it requires the reorientation of firms towards production and innovation of higher added value, according to Professor Hill.

Recent developments in the State of Pennsylvania illustrate the benefits to be reaped by a carefully crafted innovation portfolio (Figure 3). Recognizing an emerging opportunity for mid-sized pharmaceutical companies as a result of consolidations among the world's large pharmaceutical firms, the State government

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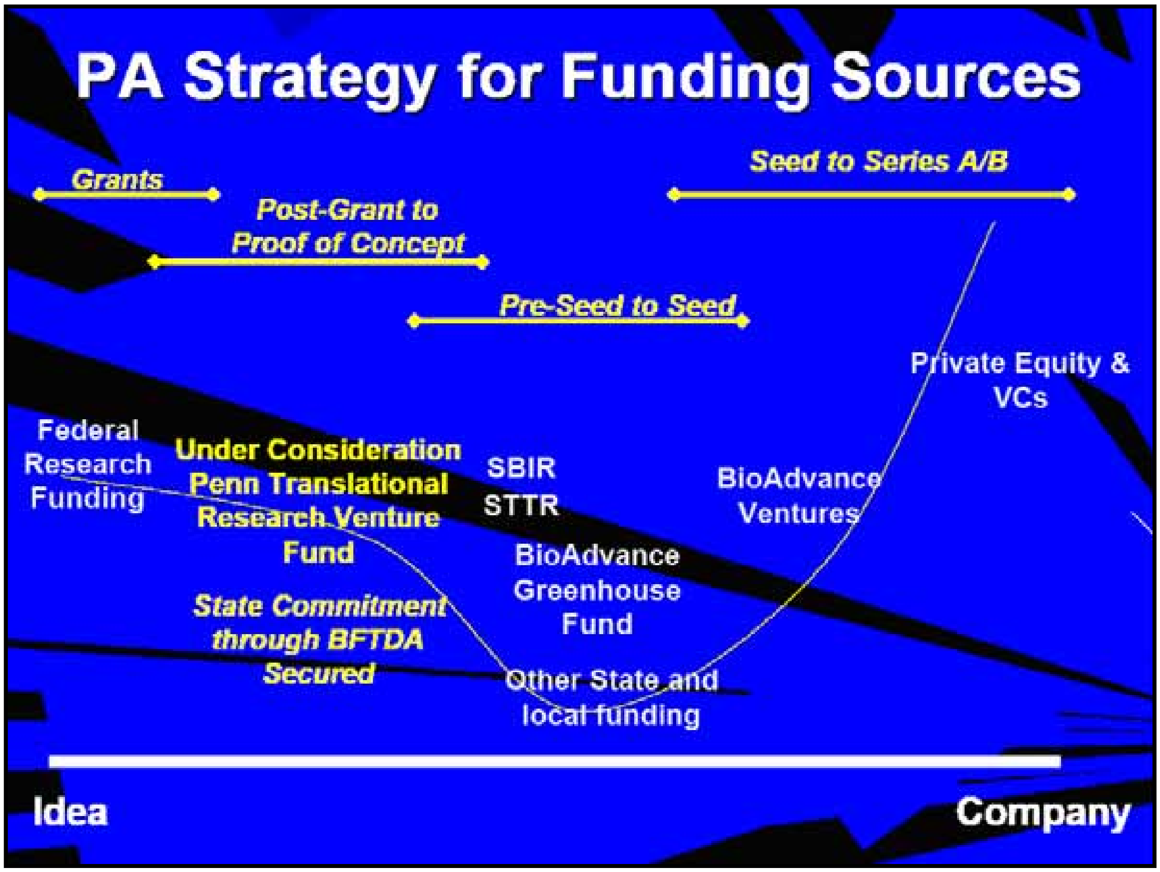
[2] Note that Hill's typology takes into account only established firms, not technology companies and small highly innovative entrepreneurial firms, which Hill calls "gazelles."

decided to use funds won from a tobacco settlement to motivate local industry to gain a "first movers" advantage in pharmaceutical R&D. "What you see here . . . is actually the first of three separate life science initiatives which are started in three different parts of the State" to move the innovation out of the university research laboratories onto the "radar-screen of the commercialization track," according to Leslie Hudson, Vice Provost of the Office of Strategic Services at the University of Pennsylvania. To fund such ventures, universities such as the University of Pennsylvania are assembling their own "translational research funds," as Hudson terms them.



Source: Leslie Hudson, University of Pennsylvania

Figure 3: The State of Pennsylvania innovation strategy.

The City of Cleveland already represents a node for biomedical research nationally and internationally. According to Ralph I. Horwitz, Dean of the Case School of Medicine, this is due to a decision made by the region's universities to establish a city-wide collaboration that would enable them to create partnerships with each of the city's major clinics and health care institutions. Geographically, Cleveland's major biomedical research facilities reside in a very compact area: the medical school and University Hospital are within a mile of both the VA Medical Center and the Cleveland Clinic. "In a somewhat more distant location is a great public safety-net hospital, Metro-Health with a health system that serves much of the West side of the city and provides care to an important component of this region's citizens," according to Dean Horwitz. University funds and resources were specifically granted to proposals that encouraged collaboration with local firms. It is this vibrant clinical community that has made the City of Cleveland a national leader in biomedical research.

Joseph Hahn, Chairman of the Cleveland Clinic Foundation (CCF), described a strategy mounted in recent years that links the resources of Case University, CCF and the University Hospital to enhance the biotechnology capability in Cleveland. Known as the "BioEnterprise Initiative," it consists of 26 companies that were formed in or recruited to Cleveland during the initiative's first 18 months, with over 440 invention disclosures reported, 220 patents filed and 65 patents issued.

Another innovation research strategy explored by workshop participants was that discussed by Sean Murdock, Executive Director of the Chicago-based nanotechnology consortium AtomWorks. By building linkages across product- and service-based industries, Illinois already has the second-largest nanotechnology research program in any State, with about 33 percent of the related intellectual and innovation capital clustered within 250 miles of Chicago. To illustrate his point, Dr. Murdock provided a partial list of AtomWorks partners (see Table 1).

As these examples illustrate, the development of specific technology competencies requires early identification of a research strategy that leverages regional strengths as well as exploits new opportunities.

Table 1. Sponsors of the Chicago-Based AtomWorks initiative.

AtomWorks Leadership

- **Chair: Iwona Turlik** – Corporate Vice President of Advanced Research, Motorola
- **Ilesamni Adesida** – Director, Center for Nanoscale Science and Technology, University of Illinois Urbana-Champaign
- **Chris Anzalone** – Chief Executive Officer, Nanolink
- **Joseph Cross** – Chief Executive officer, Nanophase
- **Alan Feinerman** – Director, Microfabrication Applications Laboratory, University of Illinois at Chicago
- **Murray Gibson** – Director, Advanced Photon Source, Argonne National Labs
- **Lewis Gruber** – Chief Executive Officer, Arryx
- **Hermann Grunder** – Director, Argonne National Laboratory
- **Chip Hardt** – Partner, McKinsey & Company
- **Don Jacobs** – Dean Emeritus, Kellogg Graduate School of Management
- **David Jacobson** – Partner, Sonnenschein, Nath, and Rosenthal
- **Heinrich Jaeger** – Director, Materials Research Science and Engineering Center, University of Chicago
- **Steve Johns** – Executive Vice President, Ardesta
- **Tarsem Jutla** - Director of Innovation, Caterpillar
- **Clyde Kimball** - Director, Nanotechnology Center, Northern Illinois University
- **Jay Kouba** – Vice President of Chemicals Technology, BP
- **Jack Lavin** – Director, Illinois Department of Commerce and Economic Opportunity
- **Derrick Mancini** – Associate Director, Center for Nanostructured Materials, Argonne National Labs
- **Manuel Marquez** – Director, Nanotek Consortium, Kraft
- **Matt McCall** – Partner, Portage Draper Fisher
- **Stephen Mitchell** – President, Knight Group LLC
- **Sean Murdock** – Co-Founder and Executive Director, AtomWorks
- **Paul O'Conner** – Executive Director, World Business Chicago
- **Mark Ratner** – Co-Director, Institute for Nanotechnology, Northwestern University
- **Dennis Roberson** – Vice Chancellor, IIT and former CTO Motorola
- **Carlo Segre** – Vice President of Research, Illinois Institute of Technology
- **David Swain** – Chief Technology Officer and Office of the Chairman, Boeing
- **Tom Thornton** – Executive Vice President, Illinois Coalition
- **Vijay Vasista** – Chief Operating Officer, Nanosphere
- **Pierre Wiltzius** – Director, Beckmann Institute, University of Illinois Urbana-Champaign
- **Max Yen** – Director, Materials Technology Center, Southern Illinois University

Source: Sean Murdock, AtomWorks

Building a Regional Environment

> *"The aerospace industry has been effective at developing partnerships between industry, government, and the labs."*
>
> Peter V. Buca, Parker Hannifin Corporation

A region's innovation environment comprises of myriad components that vary dramatically from region to region. Historically, areas such as California's Silicon Valley or Boston's Route 128 have flourished because of strong entrepreneurial cultures apparently lacking in other parts of the country. [3]

Citing the work of Annalee Saxenian, workshop participant Dan Berglund, President and CEO of the State Science and Technology Institute, suggested that a successful regional innovation environment requires many if not all of the following elements:

- Intellectual infrastructure
- Spillovers of knowledge
  - From universities
  - From informal networks
- Physical infrastructure
- Technically skilled workforce
- Capital
- Entrepreneurial culture
- Quality of life

The Federal Government, the States, universities and industry may each play a role in fostering a regional innovation environment. According to Dr. Berglund, a key to success is a clear understanding among partnering organizations as to when the "appropriate partner" should take the lead. "It is very important that the Federal Government rebalance its portfolio of economic development programs. We are working on a system that was essentially developed in the 1960s, and it desperately needs to be updated," says Dr. Berglund. "Similarly, we need to cut across agency boundaries and have some common dialogue. There is activity occurring at NSF, at Commerce, at Energy, at Labor, but there doesn't appear to be any discussion or cross-coordination between those agencies."

Several panelists acknowledged the important role that the University and Small Business Patent Procedure Act of 1980 (PL 96-517, more commonly known as the Bayh-Dole Act) played in creating opportunities for technology transfer from the university to industry. According to workshop participants, the success of the Bayh-Dole Act is a result of the framework that it provides to universities and industry to enable them to draw from each other's strengths while acting as partners in innovation. Such partnerships reduce duplicative research, provide cost savings to each member, and ensure the proper use of research and development results.

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[3] One workshop participant noted that the U.S. orientation toward youth culture might be helping to foster a climate of entrepreneurship. For many years, the average age of entrepreneurs was in the mid-20s, at which age individuals may be more inclined to take the types of risks associated with entrepreneurial endeavors.

Likewise, the Stevenson-Wydler Technology Innovation Act of 1980 (PL 96-480) fostered a strong national policy supporting transfer and utilization S&T resources of the Federal Government. Examples of other important related legislation include the Small Business Innovation Development Act of 1982 (PL 97-219), the National Cooperative Research Act of 1984 (PS 98-462), and the Federal Technology Transfer Act of 1986 (PL 99-502).

States also face challenges in their attempts to sustain technology-based economic development. Many States, in fact, have yet to recognize that investment in science and technology (S&T) is a long-term approach that goes beyond most political cycles and traditional economic development policies. State S&T authorities also identified the lack of strong State-level S&T leadership as a primary barrier to innovation-based economic development (for more on this topic, see Appendix B).

Speaking from an industrial perspective, Gil Van Bokkelen, the Chairman, President, and CEO of Athersys, Inc., identified inefficiencies in public and private research funding as a major challenge to the development of a successful biotechnology innovation environment. To emphasize his point, Dr. Van Bokkelen likened pharmaceutical firms to large ships that are difficult to maneuver, and biotechnology companies to small boats that are fast and nimble. In his view, investment in biotechnology firms will generate healthcare solutions that are safer and more cost effective while at the same time arresting spiraling national healthcare costs.

Forming Regional Partnerships

> *"...Biotechnology is an emerging sector that has excellent potential for continued and sustained growth."*
>
> Kathie L. Olsen, Office of Science and Technology Policy

Effective partnerships bring innovators together in the pursuit of common regional interests. In technology-based economic development, the four principal innovators are the Federal and State governments, universities, and industry. Each innovator has its own, very different, goals. The Federal Government emphasizes support for basic research and intellectual infrastructure. State governments focus on creating jobs through regional economic development while providing the core support and physical infrastructure for the university system. Universities specialize in producing an educated workforce, conducting research, and—in the case of land-grant institutions—providing a community service. Private industry is primarily oriented toward organizing its activities so as to maximize profits.

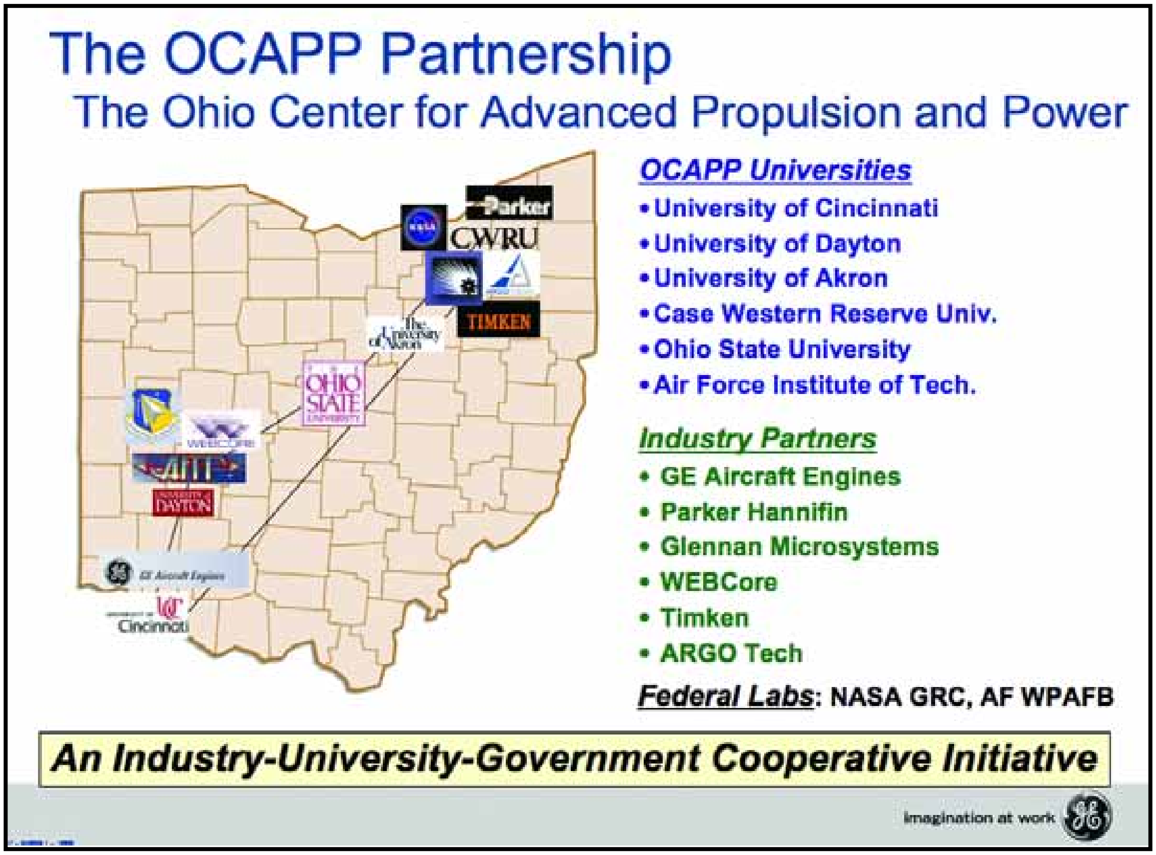
The challenge facing the promoters of regional economic development is to find incentives for these very different actors to work together for the promise of common benefits. As illustrated in the previous section, however, successful partnerships are indeed possible.

The Manufacturing Extension Partnership (MEP) at the United States Department of Commerce has identified three features that characterize successful partnerships:

- The appropriate partner takes the lead.
    - The Federal Government directs the overall program while the States administer and implement the program's various aspects.
    - The most successful MEP programs feature State contributions of matching funds.
- The focus is clearly on a stated goal, such as providing technical and business assistance to small manufacturers.
- All involved parties consult extensively with each other.

Regions are well suited to form cooperatives for economic development because their participants are likely to share similar objectives. For example, the Ohio Center for Advanced Propulsion and Power (OCAPP) is a partnership that pulls together key universities in Ohio including the University of Cincinnati, Dayton, Akron, Case Western Reserve, Ohio State, and the Air Force Institute of Technology (AFIT) (Figure 4). NASA's Glenn Research Center and Wright-Patterson Air Force Field in Dayton, representing the government, work together to sponsor and conduct direct research to benefit regional firms such as Parker Hannifin, Glenn Microsystems, WebCore, and Timken.

Several panelists recommended that regions develop strategies for improving frameworks for cooperative innovation-based economic development. Improvements could include closer collaboration between States and the Federal Government in the formulation of Federal programs, and the creation of initiatives designed to promote economic development through S&T.



Source: Michael Benzakein, OCAPP

Figure 4: Partners within the Ohio Center for Advance Propulsion and Power.

Funding the Innovation Machinery

> *"There has been a sea change with regard to the attitudes of States and the relationship between the States and the Federal Government vis-à-vis economic development based on science and technology."*
>
> Bernadine Healy, PCAST member

If people, equipment, and facilities could be said to represent the machinery of innovation, then capital is its power source. As an example, Michael Benzakein, General Manager of Advanced Technology & Military Engineering at GE Aircraft Engines, ascribed GE's ability to maintain its global leadership in aircraft engine sales to to the nearly $1 billion a year the company spends on product development. Dr. Benzakein noted, however, that "we cannot do it by ourselves." GE's solution was to co-establish OCAPP and invite universities, Federal laboratories, and military agencies to participate.

Panel participant James Williams, Dean of the College of Engineering at The Ohio State University, commented on the advantages and drawbacks of globalization. "It [globalization] is a 'plus' because it creates a much bigger market," he observed. "It is a 'minus' because you now let other people look under the tent and see how big this business really can be; it makes Asia and Europe more interested in getting in the game. So you now have competitors, whether you want them or not."

In the global economy, Dean Williams added, investors must pick winners and losers. Likewise, the Federal Government is sometimes a customer for industry programs, and sometimes a partner with industry in promoting general economic development. Therefore, he said, the Federal Government must sometimes make a strong commitment to industrial strategies in order for U.S. firms to compete successfully against foreign competitors, such as Airbus, that enjoy the benefits of heavy government subsidies.

Workshop participants raised other concerns related to Federal-State partnerships for innovation, including:

- S&T Education: States are cutting core support to higher education in pursuit of technology-based economic development. This trend must be reversed. Most panelists emphasized a renewed commitment to K-12 and higher education as essential for enabling the United States to maintain a position of innovation leadership.
- Higher Education: Excellence in academic doctoral research programs is associated with accelerated rates of growth of employment and per-capita income in metropolitan areas. (Hill and Lendel 2003) University funding should therefore be directed to efforts to increase the quality of higher education and not towards activities that focus on technology development.
- Venture Capital: Biomedical R&D needs further funding. "Growth capital funds"—represented by either venture capital or capital that is accessed through initial public offerings or secondary offerings—decreased by over $3B in 2002.
- Small Business Innovation Research: One of the panelists suggested that the Small Business Administration should consider rebalancing its Small Business Innovation Research (SBIR) portfolio, redirecting its emphasis from that of supporting traditional small businesses to encouraging the development of technology companies.
- Manufacturing Extension Partnership: A number of State representatives emphasized that funding for the Manufacturing Extension Partnership (MEP) should be either maintained at current levels or increased.

Summary Observations on Trends in Federal-State R&D Cooperation

> *"We have a wide array of elements that constitute our national innovation ecosystem ... States have become much more entrepreneurial as they to try to create the most effective ... investment concept."*
>
> Luis Proenza, PCAST Member

The PCAST Workshop on Federal-State R&D Cooperation: Improving the Likelihood of Success, held in June 2004 in Cleveland, Ohio, was the result of earlier discussions about the Nation's innovation ecosystem. During those discussions, PCAST members spoke with representatives from high-tech companies and State governments and concluded that State governments increasingly attempt to provide a friendly and complementary R&D environment, even though some of the people interviewed expressed dissatisfaction with the ways Federal and State programs typically intersected. As a result, the Cleveland workshop was designed from the outset to focus on Federal-State interactions and other selected components of the innovation ecosystem

The workshop revealed that States and regions have made good progress in formulating strategies for promoting S&T as integral to their economic development efforts. Many of the speakers provided examples of successful investment strategies and State or regional economic development plans. Others pointed to those situations in which the Federal Government clearly plays a strong and forthright role in facilitating economic development at the State and local levels. Still other speakers pointed to areas that required further strengthening.

PCAST is encouraged by the many "success stories" that were presented during the workshop. PCAST is hopeful that Federal and State governments will continue to develop and pursue creative ways to support innovation, including through collaborative investment in S&T and technology transfer. Such collaboration will stimulate economic growth and help to sustain our Nation's position as a technology leader.

Appendix A:
Information Brief on Innovation Systems

Background

- The ability to innovate is recognized as a chief determinant of economic competitiveness.
- To deal with the complexity of the innovation process and its changing climate, a new view of innovation as a "system" has emerged.
- The innovation systems approach emphasizes the role of different actors in innovation, their interactions, and the linkages between the actors and their environment.
- Policymakers attempt to influence innovation both by creating direct incentives (e.g. partnerships) and indirectly by influencing environmental factors.
- This brief introduces the concept of innovation systems.

The Importance of Innovation

Technical change is the result of *innovation*—a process that begins with the invention of a new product or process and concludes with its successful commercialization and diffusion. In today's global, fast-paced, and highly competitive economic environment, the ability to innovate is a key determinant of economic performance and competitive advantage. (Schumpeter 1934; Solow 1956; Romer 1990; Porter 1991)

> *Innovation strategies are shifting. Although companies of all sizes, government laboratories, and universities all continue to participate in the innovation process, formal and informal collaborations and partnerships among these players are rapidly assuming greater significance.*

A Systems Approach to Innovation

Innovation is a complex process that experts increasingly characterize as occurring within a system of complex relationships. This *innovation systems* approach is concerned with the set of relationships among the various actors. It examines the ways in which the flow of information among people, enterprises and institutions brings about technological change. (Lundvall 1992)

A systemic view of innovation requires consideration of the progenitors of innovation, as well as of the environment within which innovation occurs. While early analyses of innovation systems focused on activities at the national level, more recent analyses have broadened their focus to include regional and sectoral systems as well. (Nelson 1993; Cook, Uranga, and Etxebarria 1997; Malerba 2002)

The factors that characterize national innovation systems—institutional environments, organizational relationships, availability of capital, conditions of demand, and availability of skilled labor—tend to differ across regions. As a result, many analysts consider the regional innovation system to be the more appropriate unit of analysis. (Cooke, Gómez Uranga, and Etxebarria 1997) Analysis of regional innovation systems focuses on the presence and growth of "clusters" of innovation. The concept of "clustering" is explored in detail in Appendix C, "Clusters for Economic Development."

The Roles of Actors in Innovation Systems

Institutions in an innovation system, whether at the national, regional, or sectoral level, can be divided into five general categories: (OECD 1999)

1. Local, regional, national and international governments set broad policy directions.
2. *Private enterprise* contributes to the development phase of innovation, finances research institutes, and supports other market-related activities.
3. *Universities* and related institutions provide key knowledge and skills.
4. *Bridging institutions*, also called technology centers, technology brokers, business innovation centers, technology transfer organizations, joint research institutes, and patent offices, play important—if underappreciated—roles as intermediaries between other actors.
5. Other *public and private organizations*, such as venture capital firms, public laboratories, and training organizations, which play various support roles in the innovation system.

These five actors form the central core of the innovation system; collectively the actors produce, use, and diffuse knowledge. Interaction among the actors can take the form of competition, transaction, and networking.

The innovation system exists within a broader economic context that influences, and is in turn influenced by, the actors. Contextual factors include:

- Market conditions, such as the demand for innovative products and the costs of the natural resources and intermediate goods required to produce them.
- Physical infrastructure required to produce and transport goods.
- Education and training of the participants in the innovation system.
- Regulatory conditions, to the extent to which they may create incentives for, or barriers to, innovation.

The Role of Policy in Innovation Systems

Traditionally, the rationale for government intervention in science and technology has been based on the concepts of market failure, science push, or market pull. (Branscomb and Keller 1997) A common criticism of these approaches is that they assume a linear view of innovation and ignore the innovation environment. (Bozeman 2002)

In contrast, a systems approach treats innovation as a process that is continually shaped by a variety of socio-economic factors that are in turn driven by specific policies. By focusing on the *system* rather than on the *market*, the systems approach allows policymakers to identify and react to innovation challenges.

Planners and policymakers at all levels of government use a variety of monetary and fiscal instruments to attempt to influence innovation, both directly (by creating incentives for innovation) and indirectly (by influencing contextual factors).

Table A-1 illustrates how the concepts described above relate to each other. The table lists three key ways that policy can be used to support innovation. Specific examples of how each policy works in practice, the actors responsible for carrying out the policies, and the form in which the policies are implemented are all listed.

Table A-1: Policy Directions, Actors, and Mechanisms

What can policy do?	How?	Key Actor(s)	Mechanism of Action
Build an innovation culture	Remove regulatory barriers to entry when appropriate.	Government	Indirect (regulatory conditions)
	Provide incentives for venture capital funding	Government, private enterprise	Direct
	Remove obstacles to risk taking (e.g. bankruptcy law)	Government	Indirect (regulatory conditions)
Enhance technology diffusion	Promote extension and technical assistance programs to disseminate technology and codify knowledge	Government, bridging institutions, other public/private	Direct
	Education policies that emphasize lifelong learning	Government, universities, private enterprise	Indirect (education and training)
	Competition and anti-trust policies that allow for firms' co-operation and alliances	Government, private enterprise, bridging institutions	Indirect (regulatory conditions)
	Promote collaboration among firms, universities, and government laboratories	Government, private enterprise, universities	Direct
Encourage research and development	Fund a robust research and development portfolio	Government, universities, private enterprise	Direct
	Provide incentives for companies to invest in research and development	Government, private enterprise	Direct
	Education policies that emphasize lifelong learning in science and technology fields	Government, universities, private enterprise	Indirect (education and training)

Source: OECD 1999, 64-68

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Appendix B: Information Brief on States and Innovation

Background

- States engage in the market economy by adopting entrepreneurial approaches that emphasize local strengths.
- The development of science advisory capabilities at the State level has facilitated S&T-based economic development.
- The formation of effective partnerships throughout the innovation system has led to advances in research and innovation.
- This brief summarizes State efforts to promote innovation focusing on best practices and lessons learned from S&T-based economic development.

Introduction

States are increasingly and systematically using science and technology (S&T) as an engine of economic development. This trend, which began to accelerate in the 1980s can be attributed to a number of factors, including reconsideration of industrial recruitment strategies. (Eisinger 1988)

In 1992, the Carnegie Commission on Science, Technology, and Government recognized these developments in their report, *Science, Technology, and the States in America's Third Century*, which reaffirmed the role of States in the United States innovation system. Specifically, the Commission recommended that State Governors' offices include an appropriate (S&T) advisory apparatus and establish an interstate compact to enable the States to identify the "...policies [that] work best in a decentralized and variegated nation." (Carnegie Commission 1992)

In the decade following the Carnegie report, States have designated S&T advisors, S&T advisory boards, or at least an S&T-based function that facilitates educational, technical, and economic development. (Berglund and Clark 2000)

State S&T Technology Initiatives

S&T-based programs now appear regularly in State-level economic development agendas. (Coburn and Berglund, 1995). Such programs rely on the formation of partnerships and new relationships among industry, universities, and other organizations. The following typical examples illustrate the range of S&T-based initiatives currently being implemented around the country:

- **Ohio:** The 10-year, $1.6 billion ***Third Frontier Project*** initiative aims to create high-wage jobs for the State, and more broadly to make Ohio a leader in innovation. Key core areas of the project include advanced materials, biosciences, information technology, instruments, controls, electronics and advanced manufacturing and power and propulsion.

Uniquely among the States, Ohio has invited the National Academy of Sciences (NAS) to participate in the State's grant review process. NAS reviewers are distinguished scientists, business leaders, and entrepreneurs. As a result, project proposals are evaluated not only on the basis of scientific merit but also on their commercial prospects. (Samuel pers. comm. 2004)

- **Georgia:** The ***Georgia Research Alliance (GRA)*** was founded in 1990 as a partnership between research universities in Georgia, the business community, and the State government. Its mission is to foster economic development within the State by developing and leveraging the capabilities of research universities, as well as assisting and developing scientific and technology-based industry, commerce, and business. (Bozeman 2000)

  The "hub" of the GRA is the Eminent Scholars program, which recruits world-class scholars to lead key research and development initiatives at Georgia's universities. The GRA also supports research centers in emerging technologies that both support university-based research in these fields and build industry-university connections. The GRA's collaboration model was the first, and remains among the most successful, of the State-level technology-based economic initiatives. It has become a national model, and S&T programs in many States, including Ohio, emulate it. (Berglund pers. comm. 2004)

- **New York:** The ***New York State Office of Science, Technology and Academic Research (NYSTAR)*** coordinates an S&T program that, since 1999, has leveraged more than $1 billion in public and private funds to spur Statewide technology-based economic development. As a collaborative enterprise, NYSTAR's role is to continually communicate State goals and objectives to its various partners.

  NYSTAR is creating a system that ensures that all participants—principal investigators, university administrators, and university's government liaisons—are kept jointly aware of project status and informed of their roles in any decisions that need to be made. NYSTAR managers have also developed a system of tailored newsletters and other devices to communicate information to universities, industry, and policymakers. (Denn pers. comm. 2004)

- **Oklahoma:** The ***Oklahoma Center for the Advancement of Science and Technology (OCAST)*** is the State's umbrella organization for S&T-based economic development initiatives. The program frequently brings together ad-hoc committees of scientists and business experts to develop and deploy technology plans for the State.

  OCAST also funds Oklahoma's highly effective 12-year-old manufacturing extension program—the ***Manufacturing Alliance***—that has emerged as a model for technical assistance programs. The Alliance has a team of brokers, agents, and engineers drawn from Oklahoma State University who work directly with local companies to help them diagnose problems, locate appropriate sources of technical expertise, and obtain resources to enable them to achieve effective, affordable solutions. This cost-effective program taps both public and private sources of assistance, including industry specialists, who track developments relevant to the State's major manufacturing industries. (Stickley pers. comm. 2004)

- **North Carolina:** North Carolina's ***Research Triangle Park (RTP)*** is a public/private, planned research park that brings together the S&T capabilities of Duke University, North Carolina State University, and the University of North Carolina. About 137 organizations and 41,600 employees work in the RTP, of which 104 are research companies with over 40,000 research employees. In terms of employees and acreage, RTP is the largest research park in the United States. (Link and Scott 2003)
- **Pennsylvania:** The ***Innovation Partnership*** is a collaboration of economic development agencies in the Commonwealth of Pennsylvania, including the Pennsylvania Small Business Development Centers, The Ben Franklin Technology Partnership, Pittsburgh-based Catalyst Connection, Innovation Philadelphia, and the Pennsylvania Life Science Greenhouses. The partnership has been designed to increase both the quantity and the quality of Small Business Innovation Research (SBIR) proposals through marketing, proposal preparation, and proposal assistance. 4

[4] See the Innovation Partnership website at http://www.innovationpartnership.net/.

Partnerships for Innovation

Effective partnerships bring together Federal, State and local governments, private sector firms, and academic organizations to identify, implement, and promote sustainable regional and local economic development. State-oriented partnerships can take the form of *Intrastate, Interstate, State-Federal, and Federal-State* collaborations.

Intrastate partnerships, established among various actors for the purpose of innovation, are most naturally built and sustained at the county or multi-county level. Consisting of clusters that show strong connections between resident university, industry and other Federal and State development forces, they build on regional linkages and cluster development. Examples of successful intrastate partnerships include Silicon Valley, Research Triangle Park (RTP), and Boston's Route 128.

Interstate partnerships are primarily between and among States. These partnerships have multiple objectives, including: marshaling resources to attract Federal funding; consolidating and sharing research facilities and equipment; and collaborating with regional industry.[5]

State-Federal partnerships originate at the individual State level, and bring together various local elements to make use of Federal expertise or funds. The initiative for cooperative action comes from the State, which takes a position of leadership and brings together various partners, including Federal agencies and other bodies for technology development.

Efforts to Promote Sectoral Growth

States have become increasingly active in sector-specific efforts with as many as 41 States having one or more efforts in support of biotechnology R&D. Key factors that appear to contribute to success in the biosciences at the State level include:

- Investing in building the research capacity of their universities and other research institutions,
- Encouraging academic-industrial interactions,
- Making capital available to bioscience companies,
- Providing support for bioscience entrepreneurs and emerging bioscience companies,
- Putting in place programs to meet the workforce needs of bioscience companies, and
- Supporting policies designed to move technology into commercial products and services.

Source: *Laboratories of Innovation: State Bioscience Initiatives* Battelle, SSTI, 2004

Federal-State partnerships, on the other hand, are initiated by Federal agencies and departments, and include basic, applied, and development funding.[6] Examples of successful Federal-State partnerships include:

- ***Experimental Program to Stimulate Competitive Research (EPSCoR)***: "was established in response to congressional concern about the geographic concentration of Federal funding of academic R&D.

[5] The Inland Northwest Research Alliance (INRA) is a non-profit scientific and educational organization made up of eight Western research universities. INRA's research programs are collaborative in nature and bring together the participating institutions, governmental partners and industries from the participating States. INRA also educates future scientists and engineers by delivering novel educational programs throughout the region covering the eight States.

Universities in states designated as EPSCoR states receive special, merit-based support aimed at strengthening their capability to compete successfully for Federal R&D funds" (NSB 1996).

- ***Small Business and Innovation Research program (SBIR)***: Created in 1982 as a multi-agency grant and contracting program that strengthens the role of small firms in Federally supported R&D by assisting in the commercialization of products that advance agency missions.
- ***Advanced Technology Program (ATP)***: Established to support emerging and enabling technologies for improved products and industrial processes that promise significant commercial payoffs and widespread benefits to the Nation.
- ***Manufacturing Extension Partnership (MEP)***: Established to strengthen the global competitiveness of U.S.-based manufacturing by providing information, decision support, and implementation assistance to smaller manufacturing firms to enable them to adopt new, more advanced manufacturing technologies, techniques, and practices.

Barriers to Effective Partnerships

Even when a State forms a partnership having shared visions and goals, barriers may arise over time. Priorities of the partners may change due to changing legislative mandates, technologies, and political priorities. Budget pressures may further strain relationships.

Recent interviews with S&T advisors to governors, academic experts and other observers revealed the following about barriers to partnerships for promoting innovation:

- Several State advisors identified regional and local problems as barriers—not only to collaboration, but also to technology-based economic development in general. Several interviewees noted that the disparate nature of local political goals can form barriers to the presentation of a unified case for State-Federal partnership proposals. Likewise, States also emphasize the importance of leadership, encourage a proactive approach, and foster a risk-taking culture among members of the local industry community that encourages the development of partnerships.
- Other innovation experts suggested that S&T policy advisors and indeed the S&T-related State agencies have very little policymaking power, as they are typically far removed from the legislative process where funding decisions are made. This situation may also work to undermine the representative power and influence of State-level S&T advisors with the Federal government.
- Some State observers expressed their belief that the Federal government is hesitant to fund civilian technology programs, specifically those that are close to market activities, such as those on the verge of becoming commercially viable.
- Some State policymakers advocated changing the framework for performance evaluation to better take note of the spirit of technology-based collaborative efforts. One interviewee suggested that assessments of university-based research should incorporate technology transfer goals as well as more traditional metrics such as the number of publications.

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[6] Today, much university-based research is collaborative, and involves partnerships with industry, Federal Labs, and even State and local entities. In 2003, for example, universities received about $25 billion of the total $85 billion of the U.S. Federal R&D spending. This section, however, focuses more on explicit Federal-State partnerships rather than general support of R&D activities.

- Another expert noted that intellectual property issues can hamper the transfer of technology from the laboratory to the market. Universities are looking to obtain a return on investment—specifically, licensing revenues—for the work they are performing.

The results of the interviews reinforced the commonly held belief that cooperative technology partnerships involving State and the Federal governments can successfully bring together disparate organizations in the pursuit of common interests. Barriers arise only when the goals of the partnership are inconsistent with those of the individual partners.

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Appendix C:
Information Brief on Clusters for Economic Development

Background

- Experts emphasize the role of networks in enhancing the competitiveness of regions.
- These linkages, also called "clusters," are sectoral and spatial concentrations of business enterprises and non-business organizations.
- In general, clusters enhance economic performance of a region through increases in the productivity of member organizations.
- This information brief introduces a typology of clusters and policy options to create, enable, or sustain them.

Clusters: Definition and Typology

The emergence of regional innovation systems is conditioned by the complexities of the innovation process as well as differences in resources across the various regions . Networks of collocated and complementary institutions are widely believed to enhance the competitiveness of regions.[7] These networks are called clusters.

A cluster is a sectoral and spatial concentration of business enterprises and non-business organizations that consider cluster membership to be an important element of the organization's competitive strategy. (Rosenfeld 1996) Clustering yields a variety of benefits to its constituents and enhances a region's economic development through: (Breschi and Lissoni 2001)

- *Supply specialization*: Localized industries can support a greater number of specialized suppliers of industry-specific intermediate inputs and services, thus obtaining a greater variety of products at lower costs.
- *Labor market specialization*: Localized industries attract workers with similar skills, resulting in the creation of a pool of talented and competent labor that facilitates rapid expansion of firms and the rapid creation of new firms.[8]
- *Knowledge spillovers*: Information—especially tacit knowledge (i.e., information that is both highly contextual and difficult to codify)—flows more rapidly among collocated firms and individuals possessing social connections that foster reciprocal trust and encourage frequent face-to-face contacts.

[7] See, for example, the publications by the Cluster Mapping Project at the Institute for Strategy and Competitiveness at Harvard Business School, at http://www.compete.org/publications/clusters_reports.asp

[8] Labor market specialization may also have the effect of smoothing the effects of business cycles through the effect of large numbers. One of the three Marshallian "externalities" summarized by Krugman (1991) is that resistance to shocks is high in areas where firms belonging to a particular sector are collocated. Nevertheless, if the cluster is made up of firms that are in the same or similar industry, and the entire industry experiences a downturn, clusters may exacerbate rather than smooth such fluctuations

With respect to the spatial aspect of clusters, the increasing use of information technologies is beginning to spawn "virtual clusters" in which innovation actors are geographically dispersed. In a virtual cluster, the exchange of knowledge via computer enables each enterprise to use their particular product-or service-area strengths in ways that contribute to the overall value of the network. (Passiante 2002)

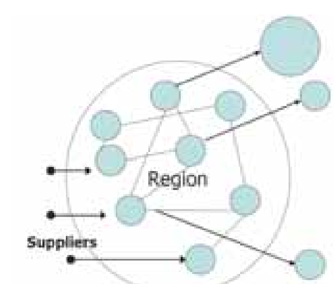
The nature and source of innovative activity varies widely among clusters, as does their structural and growth patterns. Regional economic literature classifies several typologies of clusters:

- *By the source of the activity of the cluster*. A source-based typology distinguishes among *local clusters* that are made up of local industries providing goods and services almost exclusively for the area in which they are located; *traded clusters* that sell products outside their region; and *natural resource clusters* organized around local natural resources. (Porter 2004)
- *By the goal of the cluster*. Other typologies distinguish among *trade-driven and knowledge-driven clusters* organized to share information among universities, firms, and government research organizations.
- *By the structure of the cluster*. Markusen observes four archetypical cluster development patterns: Networked Industrial District (NID); Hub-and-Spoke (H&S); Satellite/Branch Plant (S/BP); and Institutional Clusters (IC). (Markusen 1996)

Structure-Based Cluster Typology

A structure-based typology, as defined by Markusen (1996), naturally fits a discussion of the role of policy in enabling and sustaining clusters. Accordingly, this Information Brief adopts the structure-based typology for its analysis of clusters for economic development. Each of Markusen's four patterns is treated separately in detail below.

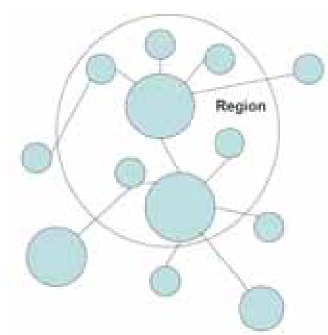
Networked Industrial District (NID) Cluster



The typical NID cluster is comprised of networks of small, locally owned firms, which enable the evolution of both a strong local cultural identity and a shared industrial expertise. Through collaboration and use of new technologies, firms in the same or related industries are able to adapt rapidly to changing markets and differentiated demand.

Examples of NID clusters include Silicon Valley, Boston (Route 128), and northern Italy.

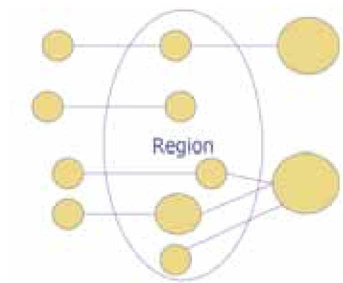
Hub-and-Spoke (H&S) Cluster



A typical H&S cluster is dominated by one or more large, vertically integrated firms that anchor smaller suppliers. Service providers often concentrate around the large firms like spokes on a wheel. Unlike networked clusters, large firms dominate the inter-firm relationships. Interactions are based more on supply linkages and less on collaborative innovation sharing. Financial and business services are tailored to the needs of the dominant firms, and labor markets are less flexible than in the NID cluster.

Examples of hub-and-spoke clusters include Seattle (Boeing) and Toyota City, Japan (Toyota).

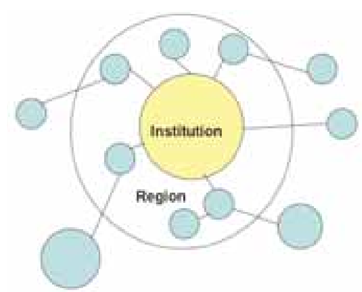
Satellite or Branch Plant (S/BP) Cluster



A typical S/BP cluster consists of a congregation of branch facilities of a large firm that is headquartered elsewhere. Governments usually place satellite clusters at a distance from major metropolitan areas in an effort to both stimulate regional development and lower the cost of business for the firm that owns the participating businesses.

A high-tech example of a satellite cluster is Research Triangle Park, NC, which represents a collection of unrelated research centers of major multinational corporations. A low-tech example of a satellite cluster is Elkhart, Indiana, where a number of auto-related branch plants have been attracted by the relatively low cost of labor in the area.

State-Anchored or Institutional Clusters (IC)



ICs, also known as State-anchored districts, are dominated by public or nonprofit entities such as R&D labs, universities, defense installations, or Government offices, which play the role of a key anchor tenant in the district.

Examples of State-anchored clusters include U.S. cities such as Santa Fe and Colorado Springs, which have grown as a result of nearby weapons laboratories, and Austin, Texas, which has similarly expanded as a result of the presence of SEMATECH nearby.

As shown in Table C-1 below, each of these four cluster patterns has different implications for the size and relationships of participating firms, for labor market flexibility, and for the policy challenges that need to be overcome for the clusters to succeed.

Table C-1: Structure-Based Cluster Typography and Characteristics

Cluster Type	Example	Firm Size	Relationship of firms within cluster	Labor Characteristics	Policy change
Networked Industrial District (NID)	Silicon Valley, Route 128	Many small, locally owned	Competition and/or cooperation	Highly flexible, tends to attract in-migration	Mix of policies required variable, making these clusters hard to form
Hub-and-Spoke (H&S)	Seattle (Boeing)	One or more large, linked to many small	Supply web	Less Flexible, low-wage jobs	Long-term growth dependent on stability of a few large firms
Satellite/Branch Plant (S/BP)	Research Triangle Park	Large, but often externally owned or headquartered	Mostly unrelated	Highly flexible, but may be transient	Relatively less local "bonding", hence firms might be "portable"
Institutional Clusters (IC)	Wright-Patterson, SEMATECH-Austin, Los Alamos	One or few large, State owned, linked to many small	Supply web	Less Flexible, stable	Technology transfer and commercialization

Clusters and the Role of Policy

As suggested in Table C-1 above, policymakers must balance a variety of challenges and opportunities that vary with the type of cluster being created, enabled, or sustained. Naturally, policies should be applied to any specific region based on an understanding of its underlying resource base and capabilities. Nonetheless, some interesting general hypotheses emerge:

- *Networked industrial districts* emerge out of a combination of factors: strong universities that both seed new technologies and attract a high-tech workforce; strong industry that can fund research while using its fruits; venture capital/entrepreneurship; and coordinating bodies that bring together the various participants. The complexity of the development of such clusters requires policies to be calibrated to specific regional factors.
- As the emergence of *hub-and-spoke clusters* is dependent on the decision of a single large private firm, fewer government policy options are available to support them. The only policy available for creating new hub and spoke clusters from scratch is to lure outside firms by creating enterprise zones or offering targeted tax incentives, and providing the workforce. However, history suggests that this approach can be both expensive and unreliable.[9]
- *Satellite clusters* require justification for both their existence and their location; a precondition to their emergence is a policy that creates an enterprise zone with supporting infrastructure. High-tech satellite clusters also appear to require vibrant local universities with disciplines of excellence that coincide with the products or services of the firms seeking to set up a satellite cluster there.
- Since *institutional clusters* form around large government-sponsored institutions, a necessary condition for creation is for the government (most likely Federal) to construct a large research facility at the site. The formation of a cluster, however, requires the flow of technologies from the facility. in addition, a strong local workforce, technology transfer, and the availability of venture funding may all be necessary for cluster formation.

[9] In 1978, Pennsylvania induced Volkswagen with a $71 million incentive package for a plant that promised employment for 20,000 workers, at a projected cost of $3,550, per job. The plant closed after 5 years, never employed more than 5,700 people, and cost the State $12,000 per job. In 1980, Tennessee won the competition for a Nissan plant with an incentive package that cost $33 million (Wilson 1989, 8), or $11,000 per job (Fulton 1988, 33). Kentucky won a new Toyota plant with an incentive package, which monopolized the States economic development budget with a price tag of between $125 and $150 million, or a cost of about $50,000 per job. In 1993, Alabama recruited a Mercedes plant with an incentive package of $253 million for a plant that was to employ a mere 1,500 workers, at a cost of nearly $165,000 per job (Fulton 1988, 39; Zipser 1995, 23; Kahan 1996, 446 cited in Trogen 1999).

Given the desire to replicate successful cluster development efforts nationwide, researchers and practitioners at the local, State and Federal level are attempting to identify the factors that make clusters “successful.” For example, the Cluster Mapping Project (Ketels 2004) or the Clusters of Innovation Initiative[10] of the Council on Competitiveness each is beginning to unravel the mysteries of cluster formation and success.[11]

Regardless of the cluster type, requisite elements for successful cluster formation include entrepreneurship and the availability of venture capital. Studies further suggest that efforts to support innovation and spur the education of skilled labor have had superior results to efforts to pick specific industries or sponsor technologies. Most of the case studies of successful clusters cast doubt on the efficacy of directed public policy efforts in “jump-starting” clusters (Wallsten 2000; Bresnahan, Gambardella, and Saxenian 2001).

Clusters should not be seen as a panacea for economic development in all regions. As Rosenfeld argues, unless clusters are carefully considered they may ignore *people who are left out, places that are left behind, and firms outside the learning networks*. The result may be lopsided regional economic development. (Rosenfeld 2002)

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[10] The project has studied “pilot” regions of Atlanta, GA, Pittsburgh, PA, Research Triangle, NC, San Diego, CA and Wichita, KS. Detailed reports of the area analyses are available from the Council of Competitiveness website and other statistical information is available at the Harvard Clusters Mapping Project website. Additional findings and methodology are discussed in Porter (2003).

[11] The Council collects comparative data on employees, wages, establishments and patents, as well as geographical (county, MSA, economic area, and State) data. These data are used to derive empirical cluster linkages and evolution. The Council also conducts interviews related to regional history, network perspectives, university assessments, business and government ties, and challenges for future growth. These comprehensive efforts supplement other evaluative techniques, such as input-output analysis that measures trade links between industry groups, correspondence analysis that aims to identify groups or categories of firms or industries with similar innovation styles, and graph analysis that shows innovation interaction matrices based on the flows of major innovations of using and supplying industries.

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[Comment: Orignal citation read: "Porter, M. (2004) “Cluster Mapping Project, Institute for Strategy and Competitiveness”, Harvard Business School http://www.isc.hbs.edu/pdf/DTI_London_2004.03.16.pdf." However, the URL is for the Ketels PowerPoint.]

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Appendix D: Information Brief on State Funding of S&T-based Economic Development

Background

- For the research described in this Brief, researchers obtained and analyzed State spending information from State organizations that perform functions relevant to S&T-based economic development.
  - Based on respondent information, States appear to organize their S&T-based economic development using at least one of four models:
  - A State agency charged with S&T-based economic development.
  - An S&T board, division, or department.
  - An S&T program office under a department of economic development or community affairs.
  - Cooperative partnerships or non-profit organizations.
- A full-scale study of State S&T-based economic development expenditures is both necessary and achievable.

Introduction

States increasingly are creating initiatives for economic development based on science and technology (S&T). Such initiatives promote the establishment and growth of S&T-driven companies. Despite the increasing reliance on S&T-based economic drivers, no recent systematic study of State funding of S&T-based economic development has been performed; in fact, the most recent comprehensive data on State funding of research and development (R&D) is from 1995. (Jankowski 1999)[12]

In the intervening decade, the ways that States view S&T have changed significantly. A new systematic study of State S&T funding may help answer questions such as

- Is State-level spending concentrated in just a few States, and if so, in which ones and why?
- How does State spending in 2005 compare with spending a decade ago?
- How are State expenditures influenced by Federal S&T allocations to States?
- On which specific areas are States focusing their S&T investments? For example, are States interested in nanotechnology?
- How does State support help established small businesses and new entrepreneurs?

[12] Using information collected from 1,037 State agencies and 420 academic institutions across 50 States, the study analyzed two factors: expenditures for R&D performed by or in support of State government agencies; and R&D funding provided by State governments to external parties such as academic institutions. The study led to the publication of the cited NSF Issue Brief.

At the request of the President's Council of Advisors on Science and Technology (PCAST), the Science and Technology Policy Institute of the Institute for Defense Analyses (IDA) conducted a study to assess the feasibility of conducting a full-scale study on State funding of S&T-based economic development that would answer some, if not all, of the above questions. The feasibility study collected preliminary data on State spending and used the results to identify the categories of spending that States allocate for S&T-based economic development.

This document is divided into three sections. The first outlines the relationship between R&D and S&T-based economic development. The second section explains the methodology used to collect preliminary data from States, and the third section summarizes the findings and observations, and also identifies the barriers that were encountered during the data collection phase of the study.

The Relationship between R&D and S&T-Based Economic Development

Defining S&T as it relates to economic development is a complex task. The term incorporates R&D and S&T spending, and also contains unique characteristics of its own. While a standard government-wide definition of R&D exists[13] , a similar definition of S&T-based economic development does not.

Several models exist that describe the relationship between S&T and R&D, including one used by the National Science Foundation (NSF), the Department of Energy (DOE), and the National Aeronautics and Space Administration (NASA). In those agencies, education and training are considered to be S&T activities, but not R&D. Other models consider S&T to be a subset of R&D, or else consider basic and applied research and generic technology to be separate from development and testing funding (Koizumi 2003). A 1995 National Academy of Sciences (NAS) report recommended that a Federal Science and Technology (FS&T) Budget be compiled as an alternative means of benchmarking Federal spending (Committee on Criteria for Federal Support of Research and Development 1995). In 2002, OMB introduced just such an FS&T Budget (American Association for the Advancement of Science 2002) that considers R&D and S&T as overlapping in many respects, but in other ways distinct. Based on an assessment of these and other definitions, this brief treats R&D as a subset of S&T for the purpose of assessing the feasibility of collecting State-based information in these areas.

Because the terms "R&D," "S&T," and "S&T-based economic development" represent a continuum of funding, it is difficult to demarcate exactly where S&T investment ends and where S&T-based economic development begins. The feasibility study adopted the position that State S&T-based economic development initiatives are those that promote the establishment and growth of science and technology-driven companies, and include:

- Investments in research and development, both academic and nonacademic
- Partnership programs that bring together academic, industry and government resources, e.g., centers of excellence
- Technology incubators
- Commercialization programs that provide assistance to technology companies

[13] "Research and development (R&D) activities comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." (OMB 2005) These activities include basic research, applied research, and the application of that knowledge to the creation of useful methods and products (development).

- Technology transfer programs
- Manufacturing extension programs
- Investments in science and technology infrastructure, e.g., information technology infrastructure
- Eminent scholars programs
- Investments in S&T workforce and training programs

Methodology

NSF collects data on state-based R&D expenditures via a survey of State-financed R&D expenditures at U.S. universities and colleges. As these data are readily available, the feasibility study focused on determining the availability of non-academic R&D, S&T, and S&T-based economic development spending. The methodology consisted of 5 steps:

Step 1: Organizations in each State that appeared to perform a function relevant to S&T-based economic development were identified through web-based searches using terms such as "science and technology," "technology-based development," "economic development," and "innovation," for each of the 50 States. In addition, we utilized on-line resources that provide listings of S&T-related agencies in each State.[14]

Step 2: As most State agencies did not provide spending information online, and given the limited timeframe of this study, one agency in each State that appeared to play the most central role in the State's S&T-based economic development portfolio was contacted by e-mail. Requests were made for data on State spending in two broad categories:

1. Total State government appropriations to science and technology-based economic development for the latest available Fiscal Year, as well as any other Fiscal Years that were readily available. If this information was not available, we requested details of State government allocations to the specific organization.
2. Details of S&T spending for the State/organization for the latest Fiscal Year. For example, monies spent on R&D programs, infrastructure, and providing business assistance to manufacturers.

In addition, agencies were asked whether they were the only relevant S&T-based economic development office in the State, or whether other S&T-related agencies also received State support.

Step 3: Non-responsive agencies were contacted by telephone. This method was also used to clarify information from responsive agencies.

Step 4: State budget offices in States from which no information had been received were contacted seeking the latest budget/appropriations report to identify categories of S&T-based economic development appropriations.

Step 5: When all data had been collected, synthesis and analysis was performed to determine the various categories of S&T-based economic development appropriations used by the respondents.

[14] For example, some State websites list key S&T agencies and programs (e.g., the North Carolina Board of Science and Technology, at http://www.ncscienceandtechnology.com/External_Programs.htm). Centralized sources are also available (e.g., Office of Technology Policy 2001).

Findings

Of the 50 State agencies to which requests were sent, 27 responded and 19 provided information within the allotted 3-week period; 23 States did not respond at all within four weeks.

Respondent States appeared to organize their S&T-based economic development activities using at least one of four models:

- Arkansas, Oklahoma, and Kansas have a *primary State* agency that is charged with a S&T-based economic development function.
- Idaho and California have a *designated S&T board, division or department* under either the Department of Commerce or the Office of the Governor.
- Alabama and several other States undertake S&T programs under a *department of economic development* or a *department of community affairs*.
- Georgia and several other States have *cooperative partnerships* or *non-profit organizations* that bring together State, industry and other resources to advocate and perform S&T-based economic development.

States often have more than one agency involved in S&T-based economic development activities. For example, Alabama has a Science, Technology, and Energy division under the Alabama Department of Economic and Community Affairs, as well as a Technology Network that provides assistance to manufacturers.

Activities sponsored by a given State agency vary depending on the agency's mission and its role in supporting the State's economic development. Regardless of mission and role, however, State agencies generally provide any of five areas of support:

- *Investments in R&D activities*: Based on data collected in 1995, approximately 75% of State investments in R&D activities are made at State research universities. (Battelle Memorial Institute 1998) To a lesser extent, States also support R&D activities at nonprofit R&D institutions and businesses. R&D is supported in a variety of areas, including biotechnology and nanotechnology. For example, New Jersey's Stem Cell Institute unites scientists from around the country to research embryonic stem cells.
- *Investments in S&T infrastructure*: States that require additional physical infrastructure to acquire a competitive advantage in S&T fund the development of telecommunications, information technology, and research infrastructure, as well as encourage industrial site development. For example, the Maine Marine Research Fund, sponsored by the Maine Technology Institute, supports infrastructure and equipment for Maine's nonprofit institutions, State governmental and quasi-governmental agencies, and academic institutions engaged in marine research.
- *Encouraging entrepreneurs and technology-based businesses investments*: States may allocate funds to venture capital firms to invest in S&T-driven companies, promulgate tax and regulatory policies, develop programs to provide financial assistance to S&T-based companies, e.g. SBIR, develop programs to provide technical assistance to manufacturers or small businesses; and establish incubators. For example, the Penn TAP program in Pennsylvania provides companies with free technical assistance and information.
- *Technology transfer and commercialization*: States build on the commercialization potential of technology developed by universities and Federal laboratories located in the State. The goal is to facilitate the incorporation of new technology into processes and products. For example, the

Technology Transfer Assistance Grant Program in Arkansas financially supports the transfer and deployment of technologies from universities to businesses.

- *Education and S&T workforce training*: State agencies fund training programs for technology occupations and may offer scholarship and/or loan forgiveness programs for math and science majors.

Significant discrepancies exist across agencies in terms of the definition of S&T-based economic development. For example, the Kansas Technology Enterprise Corporation includes staffing costs, which many other agencies do not. For the purposes of this feasibility study, particular expenditures were not ruled out; rather, the data collected were used to gain an overview of S&T-based economic development as identified by the individual States.

During the data collection phase, barriers were encountered that limited the ability to conduct further synthesis and analysis. The most important of these are:

- *Multiple agencies*: Many States have several agencies that each play a role in State S&T-based economic development. Given the limited time frame of the feasibility study, it proved infeasible to establish contact with all of these agencies. The study concentrated its efforts instead on agencies that appeared to play the most central role.
- *Lack of information availability*: Many agencies do not readily make spending information available. On average, State agencies required 6 business days to provide responses. Furthermore, 31 States could not or did not respond within the 15 business days allotted for a response.
- *Inconsistent definitions*: State agencies do not use consistent standard definitions to describe S&T-based economic development activities. As a result, some States interpreted requests for information more expansively than others, and the figures supplied included spending on programs ranging from broadband enhancements to healthcare expenses. While some States provided data related exclusively to economic development, others included data on State funding for education initiatives with a science focus, while still others lumped in business assistance to manufacturers while others only included data on technical support. As a result, it is unclear whether in all cases the data provided represents total State expenditures or merely subsets.
- *Incomplete reporting*: State agencies may report numbers that are incomplete. For example, one State reported State S&T funding at a level well below what might be expected given overall S&T expenditures in that State.
- *Ambiguous spending categories*: It proved difficult to separate academic from non-academic spending because it is unclear whether or not such spending was included in the Computer-aided Science Policy Analysis and Research (CASPAR) data. For example, R&D programs in some States do not distinguish between university-funded and non-university-funded R&D. Other States list total S&T funding to universities without distinguishing between R&D and non-R&D funding. Also, the definition of university funding itself is ambiguous. For example, many States will embark on research initiatives only at institutes affiliated with State universities. It is unclear whether these types of figures are included in the CASPAR data.
- *Multiple funding mechanisms*: Many S&T programs used a variety of funds—Federal monies, State matching grants, local property taxes, and private sponsorships. Unfortunately, for many States the funding levels of only one of these sources is known. For instance, NSF projects are often granted a certain amount of State matching funds, but websites for these projects generally report only total spending figures, without breakdown by source.

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