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University-Private Sector Research Partnerships in the Innovation Ecosystem

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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.

As a private sector advisory committee, PCAST recommendations do not constitute Administration policy but rather advice to the Administration in the Science and Technology arena.

PCAST follows a tradition of Presidential advisory panels on science and technology dating back to Presidents Eisenhower and Truman. The Council's 35 members, appointed by the President, are drawn from industry, educational 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.

Executive Office of the President of the United States

University-Private Sector Research Partnerships in the Innovation Ecosystem

Report of the
President's Council of Advisors on Science and Technology

November 2008

EXECUTIVE OFFICE OF THE PRESIDENT
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
WASHINGTON, D.C. 20502

November 20, 2008

President George W. Bush
The White House
Washington, D.C. 20502

Dear Mr. President:

We are pleased to send you the report, ***University-Private Sector Research Partnerships in the Innovation Ecosystem****,* prepared by your Council of Advisors on Science and Technology (PCAST). This report provides an overview of the U.S. research and development (R&D) enterprise and focuses on the critical role for university-private sector research partnerships, their potential to improve research and innovation, and the obstacles standing in the way of further progress.

The Council has previously reviewed a number of elements related to R&D investments, technology development and transfer, and Federal-State collaboration. PCAST is particularly concerned by a number of trends that are impacting U.S. competitiveness. This includes the inability to meet growing funding demands resulting from increased university research facilities and personnel. Additionally, we have observed a decrease in the number and size of industrial basic research laboratories. PCAST believes enhancing engagement of the private sector, including companies and foundations, with researchers in academia and government laboratories is increasingly vital to the health of the U.S. R&D enterprise and our technology-based economy.

The recommendations to enhance innovation and to address barriers for university-private sector research partnerships were categorized into five general areas. Fundamentally, PCAST found that the U.S. support and rewards system for R&D and technology-based innovation has become inconsistent and fractured, while several countries around the globe have created an environment that promotes collaboration and innovation. The key components for R&D success include Federal support for basic research and creating and maintaining a favorable environment for the private sector to fund and conduct R&D and manufacturing in the U.S., including R&D at universities.

PCAST hopes that this report provides a few critical areas for immediate action, while laying a foundation for a more significant restoration of the U.S. innovation ecosystem, a mission necessary to maintain U.S. competitiveness.

Sincerely,

John Marburger
John H. Marburger, III
Co-Chair

E. Floyd Kvamme
E. Floyd Kvamme
Co-Chair

November 20, 2008

The Honorable John H. Marburger, III
Director, Office of Science and Technology Policy
Executive Office of the President
Washington, DC 20502

Mr. E. Floyd Kvamme
Co-Chair, President's Council of Advisors on Science and Technology
Washington, DC 20502

Dear Jack and Floyd:

We are pleased to transmit to you PCAST's report, ***University-Private Sector Research Partnerships in the Innovation Ecosystem***, which was recently completed by our Subcommittee on University-Private Sector Research Partnerships.

PCAST formally commenced its study on these research and development (R&D) partnerships in April 2007, following a number of previous PCAST studies related to U.S. R&D funding, innovation, technology transfer and Federal-State cooperation. This study focused on addressing challenges related to current trends in the U.S. innovation ecosystem. As you know, while academic research capacity has continued to grow dramatically, the Federal R&D budget, which has remained fairly stable, is not expected to grow at a rate necessary to keep pace with these demands. Simultaneously, industrial R&D facilities have been reduced in size and number, increasingly relying on academic and government laboratories for basic research results. These changing dynamics represent significant challenges to the U.S. innovation ecosystem and this study was designed to identify opportunities (and address barriers) to promote university-private sector research partnerships, including new R&D business models.

To identify opportunities for research partnerships and to address current barriers, the Subcommittee heard briefings from a broad range of individuals from academia, industry, foundations, government agencies, and other organizations. We were very pleased at the high level of interest in this subject as described by these individuals, who represented fields and sectors including biotechnology, energy, information technology, healthcare, physical sciences and engineering, and nanotechnology, among others. In addition to focusing on several critical policy areas, the Subcommittee also developed a list of profiles of university-private sector research partnerships that are included in the report.

We presented our preliminary recommendations at the September 2008 PCAST meeting, where we noted the complexity of this broad issue that transcends fields and sectors. We also recognized the range of levels at which policy recommendations could be instructive, with academia, the private sector, Federal and State governments and other organizations all having a vital role in R&D partnerships.

Our findings and recommendations to enhance innovation and to address barriers for university-private sector research partnerships fall into five general areas: Basic Research and Innovation; Economic and Regulatory Policies Impacting U.S. Innovation and Research Partnerships; Network Models of Open Innovation; Connection Points Between Partners in the Innovation Ecosystem; and Measuring and Assessing Innovation. Fundamentally, the Subcommittee found that the U.S. support and rewards system for the innovation ecosystem has become inconsistent and fractured, while several countries around the globe have created an environment that promotes collaboration and innovation. The key components for this include Federal support for basic research and creating and maintaining an environment that is conducive for the private sector to fund and conduct R&D and manufacturing in the Unites States.

While PCAST's recommendations are designed for the President, and therefore our recommendations are primarily aimed at the executive branch, we also believe there are areas for improved coordination that may fall outside the Federal agencies and we outline some mechanisms for this to occur.

We feel the President's American Competitiveness Initiative has provided a vital framework to support many of the elements that drive innovation, and we recommend further adoption of those principles. This study calls for an even broader enhancement of the U.S. innovation system, including the adoption of novel research partnerships and further assessing models that could be scaled to a national level.

Sincerely,

Steven G. Papermaster
Co-Chair
Subcommittee on University-
Private Sector Research Partnerships

Luis M. Proenza
Co-Chair
Subcommittee on University-
Private Sector Research Partnerships

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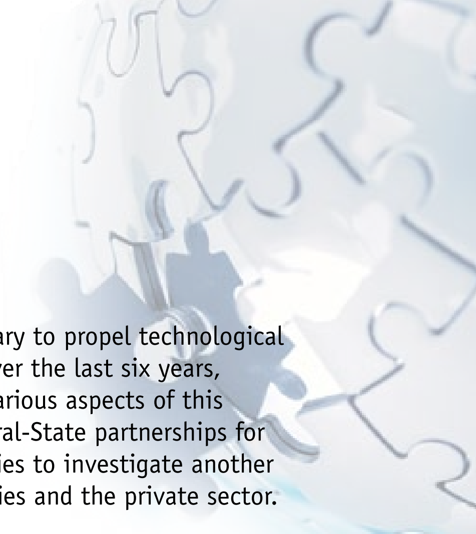

Executive Summary

The dynamic system of interconnected institutions, persons, and policies that are necessary to propel technological and economic development is commonly referred to as the U.S. innovation ecosystem. Over the last six years, the President's Council of Advisors on Science and Technology (PCAST) has reported on various aspects of this ecosystem, including trends in Federal funding of research and development (R&D), Federal-State partnerships for R&D, and mechanisms for enhanced technology transfer. This report builds on these studies to investigate another critical component of the innovation ecosystem: research partnerships between universities and the private sector.

Although many successful research partnerships exist among a range of participants from the public and private sectors, there are several new trends that PCAST considers to fall specifically within the context of university-private sector research partnerships. The first of these trends is the growing imbalance between the academic research capacity and the Federal research budget. The second development of note is the reduction in basic research performed by the industrial sector, a phenomenon most often illustrated by the disappearance of research labs such as Bell Laboratories. Private foundations such as the Bill and Melinda Gates Foundation, among others, are expanding their capacity to fund research, another trend that is expected to be important in the future. And lastly, the accelerating speed of technological development requires new methods of knowledge exchange between universities and industry so as to capture the societal and economic benefits of these innovations.

In order to recognize fully the importance of university-private sector partnerships and their role in the rapidly globalizing innovation ecosystem, PCAST reviewed the current state and historical trends of the U.S. R&D enterprise. This study involved examining inputs to the ecosystem, including funding sources and mechanisms, and outputs of the ecosystem in order to evaluate the effectiveness and productivity of the research enterprise. Finally, PCAST examined the effects of the increasingly globalized nature of the economic markets on both the inputs and outputs of the R&D enterprise.

As a critical part of its study, PCAST considered several models of university-private sector research partnerships and models of private foundations that fund such partnerships. The varied nature of these models reflects the diversity of the innovation ecosystem itself, showing that there is no "one-size-fits-all" approach for creating a successful research partnership. Nevertheless, PCAST did find numerous barriers and opportunities that many partnerships shared in common; these commonalities and the partnership models are included in the Appendices to the report.

PCAST's findings and recommendations to enhance innovation and to address barriers for university-private sector research partnerships fall into five general areas: Basic Research and Innovation; Economic and Regulatory Policies Impacting U.S. Innovation and Research Partnerships; Network Models of Open Innovation; Connection Points Between Partners in the Innovation Ecosystem; and Measuring and Assessing Innovation.

Area 1: Basic Research and Innovation

Finding:

Universities continue to serve as a primary engine for discovery research that can lead to innovation, and the Federal government remains the primary source to support basic research. PCAST found that, in spite of the increased diversity of funding sources for research performed by academia, the Federal government continues to be the primary source of funds for basic, curiosity-driven research.

Recommendation:

1. ***While exploring new partnership models, and assessing the evolving innovation ecosystem, the essential role for the Federal government in supporting basic research must be recognized and maintained.***
   The nation has benefited tremendously by following the largely linear innovation model first proposed by Vannevar Bush in 1945. While the innovation ecosystem is increasingly perceived as less linear and more

complex, the responsibility of the Federal government in maintaining a high level of basic research should continue to be recognized and upheld, even when making difficult decisions regarding funding priorities and exploring novel innovation processes.

Area 2: Economic and Regulatory Policies Impacting U.S. Innovation and Research Partnerships

Finding:

The economic and regulatory environment impacting U.S. innovation and research partnerships requires significant long-term changes.
PCAST believes that recent economic and regulatory factors within the United States are exerting a significant negative impact on innovation. Increased constraints on an economy that is generally open with measured regulations threatens the ability of the United States to continue to compete in the global environment, a consequence even more critical in the current economic downturn. Ameliorating the current situation will require several significant and long-term changes.

Recommendations:

2. ***Update and enhance the R&D tax credit to make it a more stable and effective incentive for industry to perform and support R&D.***
   While continuing to support actions that would ensure greater permanency for this vital tax benefit, other modifications to improve the credit are also recommended. Congress should address elements of the credit that limit applicability and make it difficult for companies to plan their research and use the credit. The provision of increased incentives for supporting basic and discovery research rather than more applied research would also stimulate support for higher-risk innovative research programs. The Administration should continue to work with Congress to implement comprehensive changes to the R&D tax credit.

3. ***Develop guidance and educational tools on intellectual property and technology transfer practices for university and private sector partners.***
   The Department of Commerce, working in coordination with the National Science and Technology Council (NSTC), should develop guidance and educational tools to assist in the effective and efficient transfer of technology generated from Federally-funded research at universities to industry, serving to foster shared principles between these communities

4. ***Modify, or clarify through additional guidance, tax-exempt policies that may have an unintended negative impact on industry-supported research on university campuses.***
   The Department of Treasury, in coordination with the Office of Science and Technology Policy (OSTP), should form a task force to assess these tax exemption issues, and to provide specific recommendations of policy options to the President as appropriate. The work of the task force should include consultation with university and private-sector representatives. The work of the task force should be completed within a brief timeline of approximately six months.

5. ***Develop a task force to assess other tax policies impacting innovation.***
   PCAST continues to believe that a task force led by the Department of Commerce should be established with the goal of assuring that the United States returns to a competitive position among the community of nations with which it collaborates and competes. The task force should assess current tax policies impacting U.S. R&D innovation and competitiveness, including a comparison of foreign tax policies of major competitor countries. The task force should return to the President an assessment of current policies with a series of detailed recommendations, implementation actions and associated timelines.

6. ***Assess mechanisms to enhance Federal-State coordination to promote innovation and university-private sector partnerships.***
   The President should request a review of mechanisms to enhance Federal-State coordination of R&D policies designed to promote innovation and economic development. This should include specific recommendations for enhancing coordination, while avoiding the creation of any new policies or organizations that would impact the autonomy or authorities of States and the Federal government.

7. ***Assess options to streamline oversight structures and conflict of interest requirements while ensuring the accuracy and integrity of research and preserving the public's trust.***
   The NSTC is urged to consider options to enhance the coordination of relevant rules and regulations, through new structures, improved guidance or by updating, modifying, streamlining or consolidating regulations, if necessary. The NSTC Research Business Models Subcommittee and Federal Demonstration Partnership are currently engaged in some of these activities and should be utilized to implement this recommendation. This should involve significant agency coordination and involve consultation with impacted communities from academia, the private sector and the public.

Area 3: Network Models of Open Innovation

Finding:

Open innovation has the potential to drive technology development and partnerships in academia, the private sector, and government.
There is currently a global revolution in the performance of R&D, whereby individuals and entire regions of the globe that would historically never interact can now collaborate on a research project in real-time. These open collaborations or open innovation systems can be utilized to augment corporations existing internal R&D infrastructure and university collaborations. PCAST found that these novel approaches have tremendous potential for addressing challenging research questions. These platforms could have an amplifying effect by dramatically increasing the pool of individuals available to address a given question and decreasing the time to develop solutions, thereby ultimately decreasing the time to market.

Recommendations:

8. ***Further evaluate the impact and scalability of open innovation models.***
   The NSTC should initiate a project to further evaluate the impact of existing or novel models of open collaboration to provide solutions to scientific and technical challenges. This project should include assessments of the scalability of these platforms and the potential limitations inherent in the development and application of mass collaboration systems. The study should also explore opportunities and barriers (e.g., intellectual property (IP), mission conflicts) for universities and Federal agencies to participate in open collaboration platforms.

9. ***Federal agencies should expand the use of prizes to address certain challenging research questions.***
   "Idea challenges" and various prize systems can both serve as forms of open innovation and complement a range of diverse approaches to the promotion of innovation. The National Science Foundation (NSF) should work with OSTP to coordinate a study of prizes with a range of Federal agencies that also utilize various R&D prize programs. These efforts should carefully evaluate approaches and requirements for developing a productive prize system, through engaging industry organizations, the academic community, venture capitalists, foundations, and others.

Area 4: Connection Points Between Partners in the Innovation Ecosystem

Finding:

The connection points among partners in the innovation ecosystem need to be strengthened to reduce barriers to collaborations.
PCAST members continue to believe that connections between the various partners in the innovation ecosystem need to be strengthened. Despite the increase in cross-sector collaboration seen over the past twenty years, substantial difficulties in forming such collaborations appear to remain. Some of the barriers identified by PCAST include misalignment of cultures, management structures, and goals; as well as differences in the policies that apply to IP, proprietary information, and publication.

Recommendations:

10. ***Build on existing frameworks of successful university, government, and private sector initiatives to enhance research partnerships.***
    Given the diversity of the partnerships examined by PCAST, it is not surprising that there is no "one size fits all" approach to strengthening connection points between partners. However, there is consensus on some of the key elements or guiding principles that have been found to minimize barriers to successful partnerships. PCAST urges NSF and the Department of Commerce to build on existing frameworks such as those developed by National Academies' Government-University-Industry Research Roundtable, the University Industry Demonstration Partnership and the Business Higher Education Forum to develop a set of principles to guide public-private research partnerships.

11. ***Formalize and enhance opportunities and incentives for researchers to have flexibility in moving between academia, industry, and government.***
    Federal R&D funding agencies should continue to explore options, through grants and various fellowships, for providing researches with the flexibility to engage in sabbaticals and career transitions between academia, government, and the private sector. The Federal government should develop hiring practices and rewards that promote this within Federal agencies, and should also develop policies to encourage universities to support these career paths among their faculty. These practices can also be integrated into the structure of Federally funded university research centers and programs.

Area 5: Measuring and Assessing Innovation

Finding:

Enhanced tools and metrics for policymakers and research partners to assess the outputs of the innovation system and the demands of the individual partners (both technology and workforce) are lacking.
Despite continued concerns about U.S. competitiveness in a number of areas from science, technology, engineering, and mathematics (STEM) education and workforce to technology development and commercialization, PCAST found few robust measures and quantitative assessments exist to validate these conclusions with high confidence. Measured advances in data collection have more often been made on the inputs of the innovation system rather than on the outputs or impacts. Developing meaningful output measures for innovation remains a challenging area of research.

Recommendation:

12. ***Develop and apply improved tools and metrics to measure the outputs of research partnerships and innovation to guide policies and incentive structures.***
    Federal R&D funding agencies, in coordination with statistical analysis agencies, should further develop tools and metrics to assess the products and outputs of targeted research collaborations. These measures could be integrated into appropriate funding program requirements, and should include measurements to assess technology innovation, workforce, and productivity. Using the competitiveness and innovation priorities identified in the President's American Competitiveness Initiative (ACI), a program should be initiated to more clearly define national and industry demands for technology innovation in these areas and the type and size of the science and engineering (S&E) workforce required to meet these demands. Updated innovation measures should then further guide the modification and transparency of incentive systems, permitting enhanced research partnerships.

The United States has represented the world's vanguard in the utilization of government funds and policies to drive economic progress by supporting basic science and technology research, and we are currently bearing the fruits of that radical model. Since that time, however, our support of the innovation ecosystem has become inconsistent and fractured, while other countries have developed their own successful innovation ecosystems. The findings and recommendations in this report call for a significant restoration of the U.S. innovation ecosystem, a mission necessary to maintain U.S. competitiveness.

I. Purpose and Scope

The research and development (R&D) enterprise in the United States is funded primarily by the Federal government and a private sector that includes industry and non-profit entities. Additionally, State, regional, and local governments provide a relatively small but growing contribution. The President's Council of Advisors on Science and Technology (PCAST) has reviewed a number of aspects related to the R&D funding environment and its impacts on technology development and economic growth. PCAST reported on Federal R&D funding trends in a 2002 report, *Assessing the U.S. R&D Investment*[1], with an additional study completed in 2003 on the state of technology transfer mechanisms that encourage and support commercial development[2]. Following that report, PCAST produced a workshop report on Federal-State R&D cooperation in 2004[3]. The third important component to the U.S. R&D picture of interest to PCAST is private sector support, particularly that of research communities that also receive Federal R&D funding. This last piece, and specifically university-private sector research partnerships, is the focus of this report.

Private sector engagement with researchers in academic and government laboratories is increasingly vital to the health of U.S. R&D, and ultimately to the technology-based economy. This is because:

- The Federal R&D budget, which has amounted to approximately 11 percent of the non-defense discretionary budget over the last forty years, is not expected to grow at the exponential rate required to meet all R&D support requests from academic institutions.
- Industrial basic research laboratories have been reduced in both number and size and therefore industry has come to rely further on academic as well as government laboratories for basic research output.
- Private foundations are playing a substantial role in supporting certain areas of research, such as in medicine and healthcare.
- The escalating pace of technology development calls for enhanced and novel technology transfer processes to capture these developments.

The goal of this study is to examine approaches that can stimulate interactions between the private sector and universities, including new R&D business models that may be scalable to a national level. As part of its study, PCAST also considered policies to both catalyze interactions and address potential barriers, such as intellectual property (IP), tax policies, and organizational challenges that may arise among partners. The study is aimed at improving the effectiveness of public- and private-sector research partnerships through cooperative investments, expanding interactions among personnel, and increasing opportunities for technology transfer in its broadest sense. The report begins with an overview of the U.S. R&D enterprise.

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[1] http://www.ostp.gov/pdf/final_rd_report_with_letters.pdf, accessed October 29, 2008.

[2] http://www.ostp.gov/pdf/pcasttechtransferreport.pdf, accessed October 29, 2008.

[3] http://www.ostp.gov/pdf/fed_state.pdf, accessed October 29, 2008.

II. State of the U.S. R&D Enterprise

As the United States faces increased competition in the global market, vigorous debate continues regarding both current global competitiveness standings and potential actions to enhance U.S. competitiveness. The United States currently maintains a competitive advantage in the world principally from a predominantly free market economy and a historically robust R&D infrastructure. While the Federal government can provide, through funding and policy frameworks, an environment that supports science and technology-based innovation, the private sector and academia are principally responsible for directly maintaining and expanding the U.S R&D enterprise and thereby driving innovation.[4] Given this responsibility and the growing global competition, the strengthening and expansion of university-private sector partnerships is vital both for the success of the research enterprise and for continued innovation.

The Innovation Ecosystem

The dynamic system of interconnected institutions and persons that are necessary to propel technological and economic development has been described by PCAST and others as the U.S. innovation ecosystem (see the PCAST report *Sustaining the Nation's Innovation Ecosystem*). This ecosystem includes a range of actors from academia, industry, foundations, scientific and economic organizations, and government at all levels. While widely recognized as non-linear and iterative, in its most simplified form the innovation process can be viewed as generating both new knowledge (education and training) and technology (development and commercialization) that is moved from basic discovery research to the marketplace. In this model, the results of basic science, primarily funded by the Federal government and private foundations, are translated into applied science or basic technology, where research is in turn funded by a variety of public and private entities, with venture capital often providing additional funding as the science and/or technology mature. If the research results are successful and appropriate for the marketplace, they are then turned into commercial (or publically beneficial) processes and products that drive the economy. A host of conditions influence this ecosystem, such as legal and regulatory considerations. The organization of the innovation ecosystem is not rigidly planned with well-defined roles for the various actors. As a result, the relative positions of each actor, as well as the conditions encouraging or restraining the innovation process, can change continually.

What are now conventional partnerships between the Federal government, universities, and the private sector were originally envisioned in Vannevar Bush's famous 1945 report *Science – The Endless Frontier*. This model establishes Federally-funded university research as the primary infrastructure for basic, curiosity-driven research. Funded projects are selected on the basis of merit, and the resulting research products contribute to innovation, to the development of new technology, and to the education and training of future scientists and engineers. This model ultimately serves national interests by supporting innovation, security, public health, and the economy.

In this model the relationship between university and industry may be seen as less integrated, but is no less essential to the innovation ecosystem. Universities provide both a highly skilled workforce, and research results that industry may choose to commercialize and bring to market. At the time of its development Vannevar Bush's proposal was a bold new model; over the past sixty years it has clearly had dramatic effects on education and technology development, and ultimately on the growth of the U.S. economy as well. However, over the past two decades the dynamics of universities and the private sector, and the broader innovation ecosystem, have changed. Many industries have shifted away from research that could lead to potentially disruptive innovations, preferring instead to undertake incremental improvements on existing products and technologies. This trend is likely to accelerate. At the same time, the number of colleges and universities with research programs has expanded greatly. PCAST members note that academic institutions are increasingly relying on smaller entrepreneurial companies and researchers for science- and technology-based innovation. To better understand this shift, the report now looks in more detail at R&D funding and other inputs to the innovation ecosystem.

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[4] While not the subject of this report, Federal laboratories also play a substantial role in the U.S. R&D enterprise.

Overview of Public Private Partnerships (PPP)

University-industry research partnerships are an example of a public-private partnership (PPP), which can be defined broadly as an R&D-based relationship involving at least one private firm and at least one public-sector organization that are mutually committed to reaching a common R&D goal by pooling resources and/or coordinating activities.

Within this broad definition, five aspects of a partnership can be identified:

1. **Production** – PPPs may be distinguished by what they produce, including new knowledge that may result in measurable quantities such as bibliometric and/or economic outputs. Typically, PPPs will also produce unquantifiable forms of knowledge such as expertise, tacit "know-how," craft knowledge, and skills. They may also produce technologies including protocols, prototypes, and other translational products.

2. **Learning** – PPPs always entail learning. Formal learning within a PPP can be distinguished from informal learning or "learning by doing." The former captures training programs for faculty, post-doctoral fellows, and/or graduate students that may be a part of a PPP. The latter includes uncodified knowledge attained by individuals participating in a PPP. These two types of learning often occur together.

3. **Acquisitions and exchanges** – PPPs may also be characterized by the capital, personnel, and funding resources acquired and/or exchanged by the participants.

4. **Structure** – PPPs are most often characterized by their membership and the boundaries they span, the geographical proximity of the partners, the level of formality of the collaboration, the centrality of the collaboration, and the complexity of the collaboration.

5. **Context** – PPPs must also be framed in the broader contexts in which the PPP is situated. The context of a PPP may be disaggregated into the following categories:

    - Structural context – Constraints and opportunities for behavior and productivity that are "internal" to the partnership, for instance the amount of funding.

    - Scientific and technical context – Constraints and opportunities for behavior and productivity that are "external" to the partnership and characteristic of the broader scientific field, for instance the existence, or lack thereof, of comparable programs or projects, outlets for publishing findings, etc.

    - Institutional context – Constraints and opportunities that are related to the extent to which factors such as the academic reward structure and intellectual property rights influence the partnership's host institution and other key stakeholders.

By using the features listed above to analyze PPPs, partnerships can be separated into seven groups or "archetypes" that share common characteristics: industry support of individual university researchers via grants and contracts; permanent university laboratories funded by industry consortia; quasi-permanent university-industry research centers; university research parks; technology incubators; research joint ventures including at least one university or government partner and at least one private firms; and university- or industry-based research corporations that include at least one university or government partner. Even with these archetypes as a framework, however, an assessment of such partnerships using the variables outlined above may reveal "hybrid" forms of research partnerships.

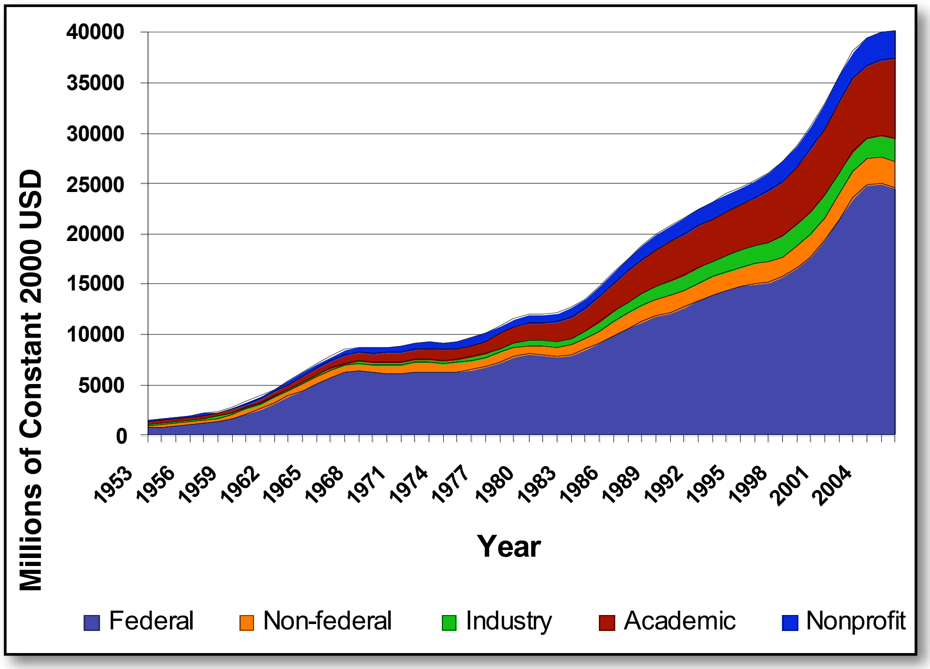
Sources: The public-private partnership definition given above combines elements of numerous definitions of research partnerships, including those of Hagedoorn and colleagues (2000), the Council on Competitiveness (1996), and Teece (1992). Note that it does not include informal interactions, which are thought to be the most common, yet the least well-understood, form of partnership.

The R&D Funding Environment and Trends by Sector

The Federal government is the major sponsor of long-term, high-risk basic research, while industry generally supports more short-term, lower-risk applied R&D. States tend to invest in research facilities, incubators, and other infrastructure and technology transfer activities that help bridge these domains, primarily motivated by regional economic development. As with other elements of the innovation system, this division of responsibilities is neither ordered nor uniformly followed, and it continues to change over time.

Changes in funding patterns over the last fifty years illustrate how the innovation ecosystem has evolved, and they highlight the role of university-private sector partnerships. Figure 1 shows funding of academic R&D by funding source from 1953–2006. The Federal government continues to provide the vast majority of funds for academic R&D. In 2006, the Federal government provided $30 billion ($25 billion in constant 2000 USD) for academic R&D, which represented approximately 61 percent of all funding. By comparison, in that same year, funds from State and local governments comprised 6.5 percent of the total, and 5 percent of funding came from industry sources. Illustrating how these proportions have behaved over time, Figure 2 shows the academic R&D funding portfolio over the past 30 years.

Figure 1. Federal and Non-Federal Academic R&D Expenditures, 1953–2006



Source: National Science Foundation (NSF) Science & Engineering (S&E) Indicators 2008[5]

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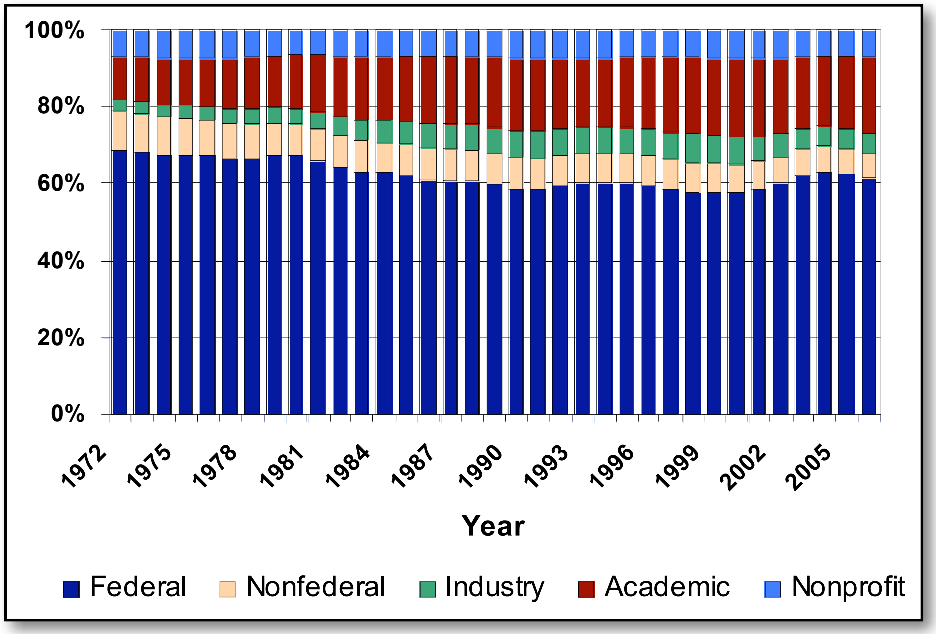
[5] National Science Foundation's Science and Engineering Indicators 2008, Arlington, VA (NSB 08-01; NSB 08-01A). Available at: http://www.nsf.gov/statistics/seind08/, accessed November 7, 2008.

Figure 2. Shares of Academic R&D, 1972–2006



Source: NSF S&E Indicators 2008

Federal Trends

As a percentage of total academic R&D funding, the peak for the Federal government contribution occurred in 1966, at a level of 73.5 percent ($4.7 B of a total $6.5B). Interestingly, and as noted elsewhere[6], Federal research budgets have historically been a nearly constant fraction of the domestic discretionary budget. As seen in Figure 3, non-defense R&D as a fraction of the non-defense discretionary budget has been sustained at a level of approximately 11 percent since the mid 1970s. While the planning, authorization and appropriation of Federal budgets have a range of competing groups and priorities, this outcome and level of non-defense R&D appears to be extremely stable.

Extrapolating this empirical pattern into the future, the rate at which Federal research funds will grow is predominately linked to the rate of growth of the discretionary budget. The domestic discretionary budget itself tends to grow linearly by a constant *amount* each year in constant (de-inflated) dollars, not a constant *percentage*. Thus the share of the budget that goes to Federally sponsored research will not grow, on average, at a fixed percentage rate in constant dollars. This creates stresses among the components within the discretionary budget and within the R&D share. If one component grows faster than the discretionary budget for several years, then it can be expected to grow at a slower rate in a subsequent period as the competing components are balanced. At present, the discretionary budget is under pressure to decline in response the growing entitlements in the mandatory portion of the Federal budget. Increasing the amount of funds available for R&D would clearly require diminishing the shares of other sectors or further increasing the deficit in overall Federal spending.[7]

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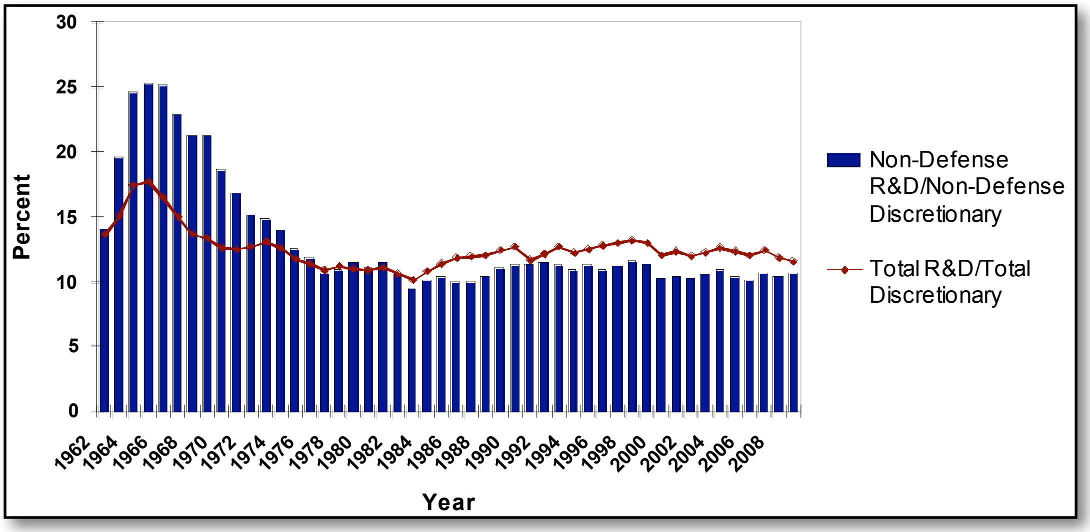
[6] Sarewitz, D. "Does Science Policy Matter?" Issues in Science and Technology, Summer 2007. Budget,"

[7] Marburger, J. "Emerging Issues in Science and Technology Policy," Talk given to the Council on Governmental Relations, October 26, 2006

Figure 3. R&D as a percentage of the non-discretionary budget, 1962–2009 (projected)



Source: OMB Historical Tables 8.7 and 9.8

Example: NIH Doubling

The doubling of the NIH budget from 1998–2003 is instructive as an example of the effects of these R&D distributions and constraints. During that period, the NIH budget grew geometrically and faster than other sectors while the overall research budget share stayed fairly constant. PCAST observed this pattern and in its 2002 report, *Assessing the U.S. R&D Investment*, and recommended that the Federal R&D budget be adjusted upward for a set period of time for the physical sciences and engineering fields to approach parity with the biomedical sciences. This funding imbalance would be adjusted through the President's American Competitiveness Initiative (ACI)[8], with the proposed doubling of the budgets of components of NSF, the Department of Energy (DOE) Office of Science, and the National Institute of Standards and Technology (NIST).

The benefits of the NIH budget doubling are clear in the profound impact observed on the nation's biomedical research infrastructure. The response of the NIH doubling has been a rapid increase in research capacity, financed by increased Federal investments, as well as a desire by State governments and the private sector to leverage these investments to secure additional funds. As a result, an expanded pool of biomedical researchers is now staffing new state-of-the-art research facilities and training yet another generation of researchers who expect to make careers in this sector. However, it is difficult to imagine how this workforce expansion and overall increase in research capacity can be maintained by the traditional system of R&D funding. New investigators and facilities will either find alternative methods to fund their research, or they will seek positions in other sectors of the economy, as the research infrastructure transforms to support other forms of R&D. This geometric growth in research capacity cannot be maintained by even the most optimistic projections for the growth rate of the Federal research budget.[9]

As a result of this growth discrepancy, research universities are increasingly forging partnerships with private sponsors and State and local governments to maintain their growing capacity. Unlike the domestic discretionary budget, the assets of the private sector *do* grow geometrically with the GDP, and industrial investment in R&D

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[8] While components of the ACI were adopted in the America COMPETES Act, the vital tax incentives and visa polices were not addressed.

[9] Marburger, J. "Emerging Issues in Science and Technology Policy," Talk given to the Council on Governmental Relations, October 26, 2006

has consequently grown much more rapidly then Federal contributions. Furthermore, many research facilities are supported by State investments, as the awareness of the role for research universities in regional economic development likewise grows.

State and Local Trends

Although the contributions of State and local governments to academic R&D have varied over time, over the last 25 years the percentage of academic R&D funded by these sources has remained approximately 6–8 percent. States have recognized the vital role of universities in supporting regional economic development, both through education and technology development. This acknowledgment by States is not new, yet more recently State governments have directly witnessed the impact that start-up companies and entrepreneurial efforts can have on job growth and regional economies. States are looking to examples such as California's Silicon Valley as models, while also realizing that these examples are difficult to duplicate. Many of these successful models required years, and often decades, of sponsorship and development, and required a combination of actors and elements that resulted in success.

Investments by State governments in academic R&D are often focused on core research topics or multidisciplinary centers and are not always clearly depicted in the data, which only include funds that State governments *directly* target to academic R&D activities.[10] Other funds provided by State and local governments are sometimes reflected as institutional funds, which are a significant component of university R&D funding, especially in supporting construction of research facilities.

Increasingly, States are also offering tax credits for company-funded R&D. In 1982, Minnesota became the first state to enact such a credit, and by 2005 the number of states offering a research credit had increased to 32.[11] Nineteen of the 32 states that offer credits provide an incremental credit with a fixed base, similar to the Federal credit, whereas ten states provide an incremental credit with a moving average, and in the remainder of the states, the credit applies to all qualified research.[12]

Several significant State programs directly aimed at increasing R&D funding were approved in 2007, for example in Arizona, where a "21st Century Fund" has been created to provide $25 million per year for graduate research fellowships, research and industry groups, small-business funding, and K-12 science and math education programs; in California, which approved $70 million for two research centers; in Florida, where $80 million was approved for a genomics research institute, as well as $100 million for centers of excellence; in Indiana, which committed $20 million for a life sciences fund; and in Washington, which set up a ten-year commitment of $35 million/year to build a Life Sciences Discovery Fund.[13]

Individual cities are also recognizing the importance of increasing funds to encourage high tech R&D in their municipalities. For example, this year New York City officials announced that they would provide a $2 million seed fund to encourage entrepreneurship and the local venture capital market. Grants of up to $200,000 will be given to seed-stage New York-based businesses. NYC Seed, as the initiative is known, is a collaboration between several city and State organizations. Fresno, California recently announced a funding opportunity for start-ups, as well.[14]

Often, these investments from State and local governments will not result in immediate observable impacts in job growth and economic development, and such initiatives should be viewed as strategic long-term programs. Although a range of State initiatives is underway, their investments can often become shortsighted and lack strategic vision, a trend that can also occur in the private sector. For example, if the programs become significant initiatives and are tied to the Governor or other term-limited leaders, they are also likely to end when that

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[10] NSF S&E Indicators 2008

[11] NSF S&E Indicators 2008

[12] NSF S&E Indicators 2008

[13] Berglund, D. "State Support for R&D and Innovation," Presentation to the 2008 AAAS S&T Policy Forum. Available at: http://www.aaas.org/spp/rd/Berglund08.pdf, accessed November 7, 2008.

[14] See: http://www.ssti.org/Digest/2008/061808.htm#Cities, accessed November 7, 2008.

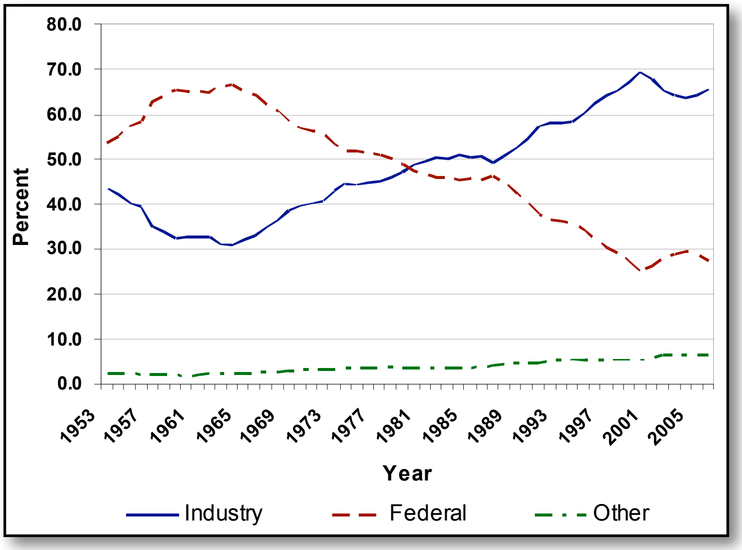
individual leaves office. Some Governors and other officials have established science and technology advisors, who can improve coordination on these issues and provide more of a strategic long-term approach to overcome these challenges.

Industry Trends

In 2006, overall U.S. R&D funding from non-Federal sources was approximately $246 billion, with the business sector both providing the largest source, 66 percent ($233 billion), of total R&D funding and performing the majority of U.S. R&D. As Figure 4 shows, the role of business was not always dominant, and it was not until 1980 when the business sector surpassed all others in its contribution to national R&D funding. This sector has maintained this position to date. Following a downturn at the beginning of this century, when industrial R&D support declined by more then 3 percent per year in real terms, between 2002 and 2006 it grew by nearly 3 percent per year in real terms.

In 2006, companies headquartered in North America increased their absolute R&D spending by 13 percent ($21 billion),[15] while companies headquartered in what are now called re-emerging nations, including India and China, increased absolute spending in 2006 by $400 million.[16] In comparison, China and India have a five-year average rate of growth of 25 percent, indicating a strong push to catch up, yet they are starting from a much smaller base than the U.S.

Figure 4. U.S. R&D expenditures, by funding sector, 1953–2006



Source: NSF S&E Indicators 2008

While support for academic R&D has never been a major component of industry-funded R&D, industry funding of academic R&D increased for the second year in a row in 2006, to a level of $2.4 billion. This $2.4 billion makes up just 1 percent of total industry R&D funding. While the level of industry support for academic research has remained fairly stable over time, there is reason to believe that both the demand and opportunities for leveraging industry investments in academic research centers are increasing.

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[15] It should be noted that a portion of R&D expenditures by U.S. companies is spent outside of the U.S., explaining the discrepancy between NSF data, which only captures U.S. R&D funding, and the data cited here (from reference 16), accessed November 6, 2008.

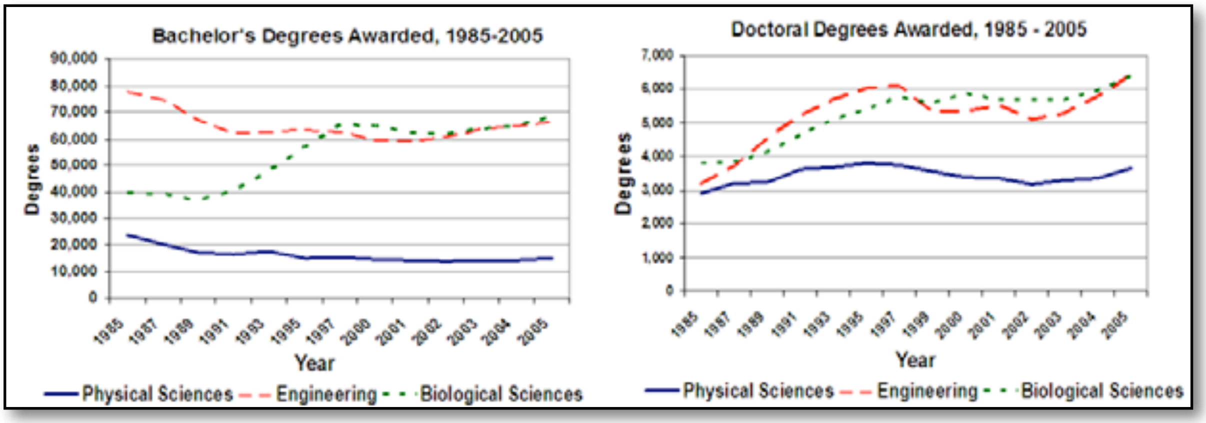
[16] Jaruzelski, B. and Dehoff, K. "The Customer Connection: The Global Innovation 1000," Booz Allen Hamilton Report, December 10, 2007, accessed November 6, 2008.

Other Inputs to the Innovation Ecosystem

S&E Graduates

The innovation ecosystem relies on a healthy supply of graduates in S&E fields. The number of bachelor's degrees in the natural sciences[17] increased 30 percent during the period 1985–2005, yet in recent years the production of bachelor degrees in the natural sciences has remained stable. Figure 5 shows that from 1985 to 2005, bachelor degree production in engineering and the physical sciences declined. During that same time, however, the biological sciences experienced a 70 percent increase in bachelor degrees. Graduate degrees in all three fields have increased, in part as a result of a rise in the number of temporary foreign residents. These trends were previously recognized in both editions of PCAST's report, Sustaining the Nation's Innovation Ecosystem (January 2004[18] and June 2004[19]). These and other reports were followed by the ACI and subsequently the American COMPETES Act, both of which called for increased R&D and education support for the physical sciences. Unfortunately, full funding for these critical initiatives has yet to be realized. Industry leaders, including members of PCAST, reported a need not only for more S&E graduates, but for S&E graduates who have skills relevant to work in an industrial setting. The text box below describes an example of one approach to provide this training, through the Professional Science Master's program.

Figure 5. Degrees awarded in the physical sciences, biological sciences, and engineering, at the bachelor degree level (left panel) and the doctoral level (right panel)



Source: NSF S&E Indicators 2008

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[17] According to NSF S&E Indicators 2008, "natural sciences and engineering" include physical, biological, earth, atmospheric, ocean, agricultural, and computer sciences; mathematics; and engineering.

[18] http://www.ostp.gov/pdf/finalpcastitmanuf_reportpackage.pdf, accessed October 29, 2008.

[19] http://www.ostp.gov/pdf/finalpcastsecapabilitiespackage.pdf, accessed October 29, 2008.

Profile : Professional Science Master's Initiative

Recent reports have focused on the need for scientists who have training relevant to industrial R&D. In 1997, the Alfred P. Sloan foundation awarded a series of grants to universities to develop the Professional Science Master's (PSM) program, with the aim of training scientists and engineers to work outside of academia by integrating science and engineering courses with education in professional subject areas such as management, law, and policy. The development of PSM programs includes input from industry so that they are designed to align with present and future career opportunities. The PSM is a two-year advanced degree program that has been established at over 60 universities, through 125 degree programs. Fields of study range from bioinformatics to forensic sciences to national defense.

PSM programs generally encourage three types of degrees, which are designed to:

- Deepen a student's knowledge beyond what can be learned in a four-year course of study, but stay within a disciplinary domain;
- Fuse scientific fields at a level of depth and complexity hard for undergraduates to achieve; for example, fusion of a field with computer or information sciences; and
- Integrate study in the natural sciences and mathematics with knowledge and training in management, law, or other professional domains.

In January 2006, the Council of Graduate Schools assumed primary responsibility for supporting and expanding the PSM Initiative, with the goal of making it a regular feature of U.S. graduate education.

The COMPETES Act contained authorizations for NSF to establish both a PSM clearinghouse and a grants program to facilitate the creation of new PSM programs. As of FY2008, no funds have been appropriated to develop these programs.

Source: www.sciencemasters.com, accessed November 5, 2008.

S&E Workforce

Using the occupational classification[20] of scientists and engineers, the size of the S&E workforce and how it has changed over time can be examined. From 1950 to 2000, the number of scientists and engineers (including technicians, but excluding social scientists) grew from under 1 million to over 4 million, as shown in the top panel of Figure 6. In fact, the only decrease of any subfield occurred from 1990 to 2000, when S&E technicians saw a drop in the number of employees. The bottom panel of Figure 6 reveals that more recently, in the early 2000s, the size of the S&E workforce experienced a slight drop in absolute numbers, while the most current data show that the workforce is growing again, albeit at a slower rate than during the 1990s. In examining any of these trends, it is critical to disaggregate the data to make projections and assessments for specific fields and populations. This can be challenging, depending on the type and source of data. Longitudinal studies are increasingly being recognized as important to measure the effectiveness of science, technology, engineering, and mathematics (STEM) education and training programs.

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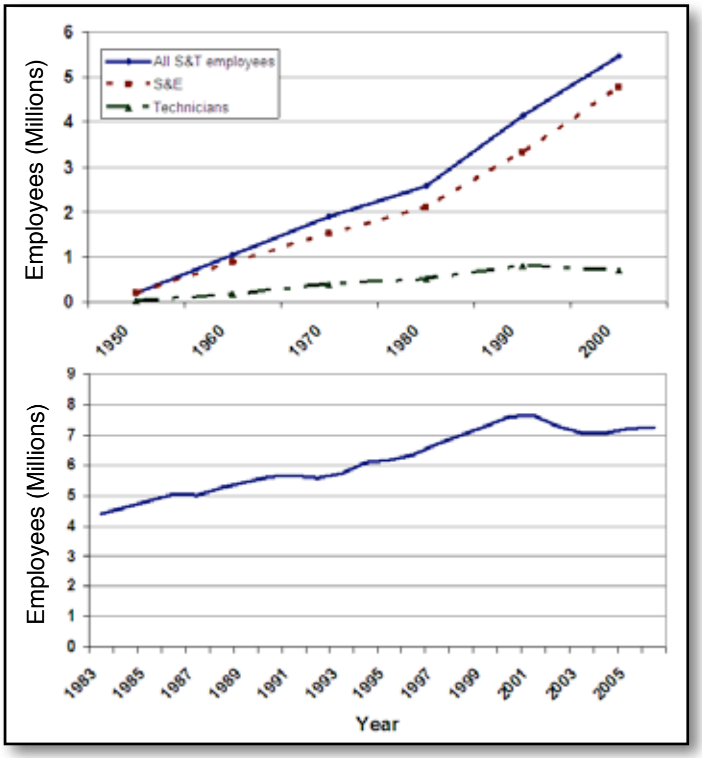
[20] From NSF S&E Indicators 2008: "The most common way to count scientists and engineers in the workforce is to include individuals who have an occupational classification that matches some list of science and engineering occupations. However, several problems arise when individuals are self-titled or employer classification codes are not reliable. In addition, this method does not capture individuals using science and engineering knowledge under titles such as manager, salesman, or writer."

Figure 6. Size of the S&E Workforce, 1950–2000 (top panel), and 1983–2006 (bottom panel)



Source: (top) NSF S&E Indicators 2008, adapted from decennial surveys of the Census Bureau. (bottom) Commission on Professionals in Science and Technology, adapted from the Current Population Survey of the Bureau of Labor Statistics.

Note: The two data sources show a discrepancy of approximately 1 million employees, a gap not uncommon when comparing sources.

Global Nature of the Innovation Ecosystem

The changing global R&D ecosystem has provided new challenges and opportunities for corporate R&D programs. Many larger U.S.-based corporations have become global multi-national corporations (MNCs) with established markets abroad. The scale and scope of R&D activities are becoming more global, and over two-thirds of companies worldwide currently distribute at least some of their R&D to other countries.[21] The natural evolution of global markets has led to the creation of offshore manufacturing and R&D facilities to enhance the support of global sales and marketing efforts. Increased connectivity to international researchers and the enhanced quality of research universities abroad together create a competitive global marketplace for R&D. Figure 7 shows the internationalization of R&D though foreign direct investments, which is just one indicator of the increasing globalization of the R&D ecosystem.

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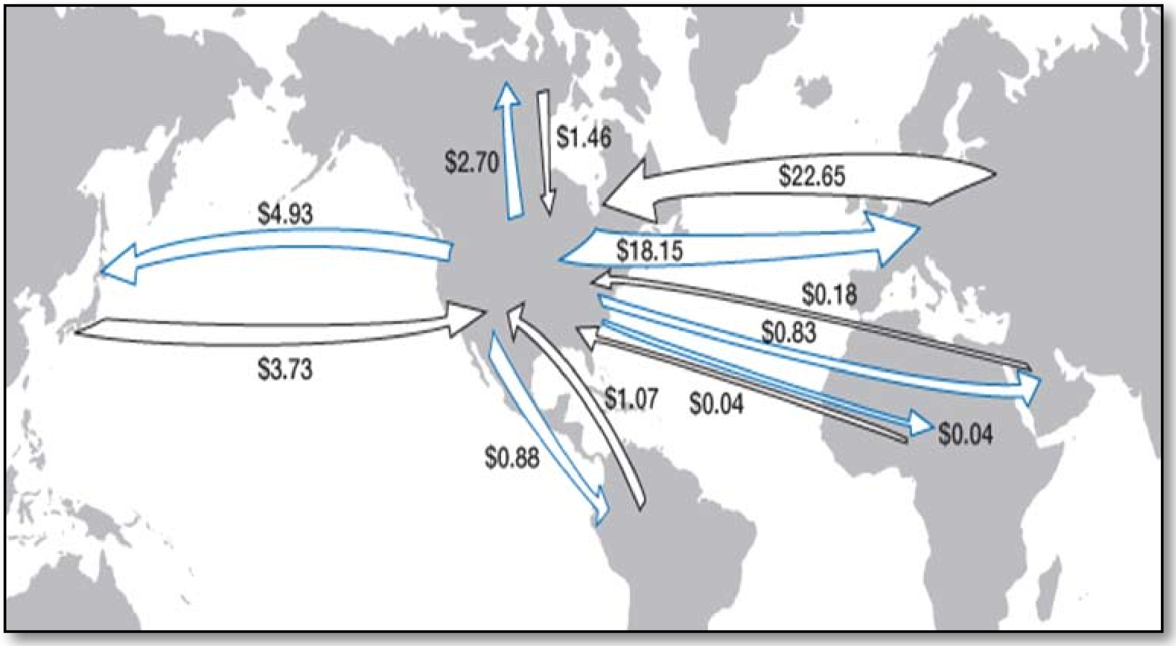
[21] "Scattering the seeds of invention - The globalisation of research and development," 2002. Available at http://a330.g.akamai.net/7/330/25828/20040914153222/graphics.eiu.com/files/ad_pdfs/RnD_GLOBILISATION_WHITEPAPER.pdf., accessed October, 29, 2008.

Figure 7. R&D performed by U.S. affiliates of foreign companies in U.S, by investing region, and performed by foreign affiliates of U.S. MNCs, by host region, in current USD (billions)



Source: NSF S&E Indicators 2008

These trends in globalization have been accompanied by significant reductions in prestigious industry R&D facilities. Bell Laboratories and Xerox are two prominent examples of companies that significantly reduced or eliminated their core research functions This could be because, in a more competitive global marketplace, some corporations have reached the conclusion that they could no longer maintain the significant capital investment required to build and operate laboratory facilities. As a result, these companies conduct less research and focus primarily on development and the identification of incremental changes to existing products. Currently, this lost industrial research capacity has not been recreated, and there is no indication that it will be in the future.

Some companies have utilized research partnerships with universities to help drive innovation, either by directly funding research or by co-locating research centers on or near university campuses. For example, Intel has established university research centers at Carnegie Mellon University, the University of California Berkeley, and the University of Washington Seattle, while the Microsoft Research Laboratory has established satellite facilities globally in China, the UK, and India.

Therefore the core research capabilities of industries are being reduced at the same time as the demand from industry for research that drives more than incremental innovation is increasing. This drives international competition to provide technologies, workforce, and overall research infrastructure. While there may be advantages to forming partnerships in the geographic area where a company maintains its headquarters, there are increased opportunities and incentives to form research partnerships with high-quality universities around the globe.

Open Innovation

Corporations and universities are taking advantage of new global open innovation platforms to tap into a vast pool of potential researchers and problem solvers who can identify innovative solutions to existing problems. Over the last ten years, several companies have formed based on this concept. Examples include Fellowforce, Innovation Exchange, NineSigma, yet2.com, and InnoCentive. All of these companies serve as platforms for companies and non-profits to present problems to a community of solvers. InnoCentive primarily focuses on R&D challenges, and their approach is examined below as one platform for open innovation.

Profile : InnoCentive's Approach to Open Collaboration

InnoCentive Seekers are primarily prominent R&D firms and non-profit institutions that collectively spend billions of dollars on R&D. InnoCentive works with the "Seekers" prior to having their R&D challenges posted on the InnoCentive Marketplace. This allows the R&D problem to be defined in terms that an audience of general scientists can understand. The challenges are categorized as 'Ideation' (short creative challenges), 'Theoretical' (a design based on an idea, but not tested), 'Reduce-to-Practice' (prototype), or 'e-Request for Proposal (a true RFP). The challenge is also assigned a monetary award value up to $1,000,000 and a deadline date. The challenge is then posted online at InnoCentive's website and is sent to the collection of over 155,000 registered Solvers, who are encouraged to submit their solutions to the problem. The community of Solvers includes engineers, inventors, business people, and research organizations from over 175 countries.

As highlighted in the appendix, intellectual property (IP) negotiations can be a major barrier to public-private partnerships. InnoCentive has developed a system to protect the IP rights of both Seekers and Solvers. Ideation challenges and eRFP challenges do not involve IP transfer. For the other challenges, Solvers initially see a brief description of the challenge and before seeing the full description are required to sign an agreement which explains confidentiality requirements and IP transfer if the Solver's submission is ultimately chosen. Solvers who submit solutions are required to give a temporary license to InnoCentive to evaluate their submission and to the Seeker firm. If the Seeker chooses the Solver's submission, the Solver transfers all IP rights to the Seeker. This system has been successful for 99 percent of awards.

Of the over 600 problems posted since 2001, approximately 40 percent have been successfully solved, a remarkable figure given that problems are typically posted by prominent R&D firms only after considered unsolvable internally. A recent analysis[1] of problems solved through InnoCentive revealed several interesting findings. Two of these findings were: (1) the more diverse the scientific interests of the solvers attracted to the problem, the more likely the problem was to be solved; and (2) the further the problem was from the solvers' research area, the more likely they were to solve it. These findings underscore the ability of open collaboration to solve seemingly insurmountable R&D challenges.

Source: www.innocentive.com, interviews with Alph Bingham

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[1] K.R. Lakhani, Jeppesen, L.B., Lohse, P.A., and Panetta, J.A. "The Value of Openness in Scientific Problem Solving." Harvard Business School Working Paper 07-050

Factors in Selecting R&D Facility Locations

A 2006 survey of over 200 multinational companies across 15 industries revealed some of the factors that influence decisions on where to perform R&D.[22] Although responses to these types of surveys often vary greatly, thereby making clear conclusions difficult, some points are worth noting. A company's decision about where to locate R&D is complicated and influenced by many factors, including whether the site is located in a developed or an emerging economy. The top four factors for determining whether a company locates an R&D facility at home or in another developed economy are quality of R&D personnel, IP protection, quality of university faculty, and university collaboration. For sites selected outside the respondents' home countries and in an emerging economy, however, the top four factors are growth potential, quality of R&D personnel, support of sales, and IP protection.

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[22] Thursby, J. and M. Thursby "Here or There? A Survey of Factors in Multinational R&D Location – Report to the Government-University-Industry Research Roundtable" National Academies Press (2006)

Thus it seems that developed economies have an advantage in attracting companies by their quality of university faculty and the availability of university partners. Several universities in countries in Asia and the European Union (EU) are beginning to change policies regarding issues such as IP and adopting practices similar to those established by the Bayh-Dole Act in the United States. This will undoubtedly have an impact on IP negotiations between these foreign universities and the private sector.

Based on PCAST's experience and several testimonials it seems clear that corporate tax policies, beyond R&D tax credits- discussed in the next section, have a significant impact on a corporation's decision on where to build and operate a facility. Recent data are hard to acquire, but the migration of R&D facilities to offshore locations has increased in recent years. Between 1998 and 2003, the share of U.S. corporate R&D sites located within the United States declined over 10 percent with China and India being beneficiaries of these relocations.[23] Surveys and other studies[24] indicate that greater efficiency, speed to market, and access to talent are the key drivers of this offshoring. Tax-related incentives do appear to be important for firms setting up manufacturing facilities. The Semiconductor Industry Association (SIA), for example, estimates that the Chinese government's tax policies are the major contributor to a cost differential to Intel of $1 billion over ten years for building and operating a semiconductor plant in China as compared to the United States. Given that there is some evidence[25] that R&D facilities tend to follow manufacturing ones, corporate tax rates are an important policy instrument to examine in the context of the national innovation ecosystem.

Assessing the Impact of R&D Facility Location

Increases in R&D employment at new domestic facilities generate improved economic development within the United States overall and in individual States through job creation, tax revenues and an enhanced workforce. Ultimately, these benefits are observed regardless of the national home of the corporation. For example, when a foreign corporation places a R&D facility in the United States, while revenue may return to the foreign owners, the United States benefits from developing and maintaining a strong R&D base, including technology development, productivity, and a highly trained workforce.

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[23] Booz Allen Hamilton and INSEAD, Innovation: Is Global the Way Forward? (n.p.: Booz Allen Hamilton, 2006), 3

[24] c.f. Thursby, J. and Thursby, M. "Here or There? A Survey of Factors in Multinational R&D Location – Report to the Government-University-Industry Research Roundtable" National Academies Press (2006); "Recent Trends in the Internationalisation of R&D in the Enterprise Sector - Special Session on Globalisation, 2008." Available at http://www.oecd.org/dataoecd/27/59/40280783.pdf, accessed October 29, 2008.

[25] Tassey, G. "Globalization of Technology Based Growth: The Policy Imperative," The Technology Imperative, ed. Gregory Tassey (Northampton, MA: Edward Elgar Publishing, 2007). Yet, other studies have questioned the importance of manufacturing and R&D facility co-location; c.f. Ketokivi, Mikko ja Ali-Yrkkö, Jyrki "Determinants Of Manufacturing R&D Co-location," Helsinki, ETLA, The Research Institute of the Finnish Economy, 2007, 28 p. (Keskusteluaiheita, Discussion Papers; ISSN 0781-6847; no. 1082)

Economic and Regulatory Policies

Economic policies have previously provided a strategic advantage to the United States in accelerating both the development of new technologies and their entry into the marketplace. However, a series of economic policies and regulatory changes within the United States, in combination with the rise of free market approaches and increased investments in science and technology abroad, have changed the fundamental global environment for innovation and competitiveness. A range of policy options, discussed in detail in the Findings and Recommendations section, can provide the ability to quickly develop and apply new technologies and increase productivity, while others can stifle innovation.

The role and impact of the R&D tax credit has been a topic of continual discussion and debate.[26] In the particular context of this study, R&D tax credits can be utilized as a method to promote industry investment in university research and education programs. Tax credits have existed in the United States since the 1980s, yet they comprise a small fraction of the R&D spending of firms (see Figure 8). While their general value has been recognized by virtue of their thirteen renewals, they have never been made permanent by Congress. The rigid nature of the policy regarding their use and the potential lack of stability in their availability reduces the utility of credits. Coordination between States and with the Federal government in their efforts to take advantage of tax credit programs can also be leveraged to enhance partnerships and exert a synergizing effect on the innovation process.

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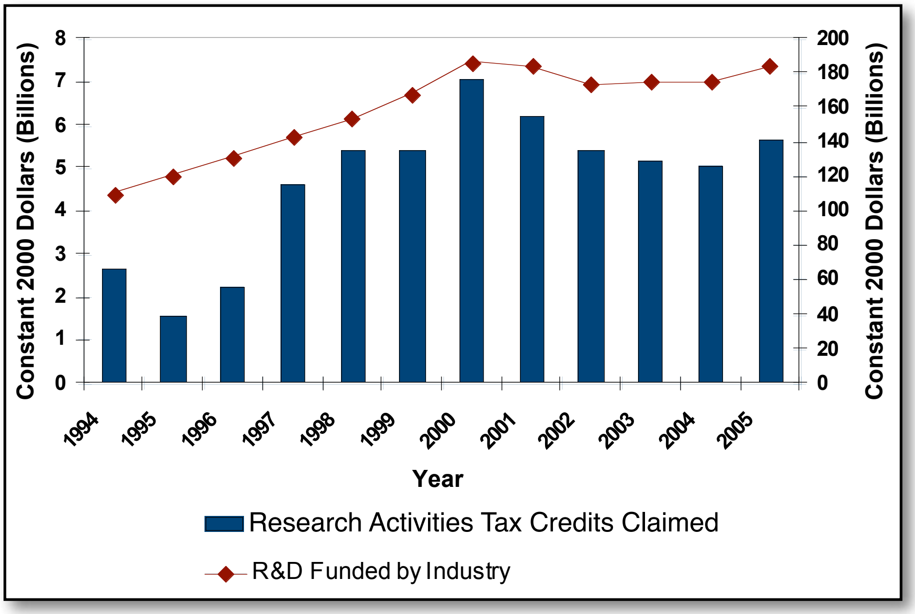
7. Tassey, G. “Tax Incentives for Innovation: Time to Restructure the R&D Tax Credit,” Program Office, National Institute of Standards and Technology, August 2007
8. *Federal Support for Research and Development*. Congressional Budget Office (CBO), June 2007
9. *The Effectiveness of Research and Experimentation Tax Credits*. Office of Technology Assessment (OTA), Congress of the United States, September 1995

Figure 8. Historical Values of R&D Spending by Industry and Tax Claims, billions of constant 2000 USD



Source: IRS SOI Tax Stats - Corporation Complete Report and S&E Indicators

Future Requirements

As global competition increases, corporations will continue to require the results of basic research and a pipeline of highly qualified scientists and engineers with the appropriate training to work in industry. As noted above, many corporations lack the core internal research facilities to perform long-term research, and will also require an increasingly specialized and diverse workforce. Government research laboratories have a critical role in research and technology development for specific applications and should continue to serve this role and receive additional support, instead of the diminishing support they are currently experiencing. Some Federal laboratories also provide large user facilities serving university-based researchers. Research universities, however, will remain the primary resource for basic research and will provide the pipeline for the future workforce. PCAST believes that university-private sector partnerships can be used to attract R&D investment and result in improved economic growth.

Outputs of the Innovation Ecosystem and the Current Incentive System

In evaluating the effectiveness and productivity of the research enterprise, including university-private sector partnerships, it is ultimately necessary to look beyond the inputs discussed above to the actual outputs, which include both the development of new technologies and the creation of human capital. These areas lack adequate metrics. Although new methods are emerging to better characterize these areas and evaluate the impact of policy decisions and Federal investments on the outputs of the ecosystem, many challenges remain.

This section discusses some of the primary elements currently used to measure innovation and successful research partnerships, particularly from the viewpoint of universities. These outputs are tied to incentive systems for faculty, university technology transfer offices, and administrators. Correspondingly, returns on investment can be a primary concern of the corporate sector. Misalignment of incentive systems and a lack of transparency can create barriers for university-private sector research partnerships.

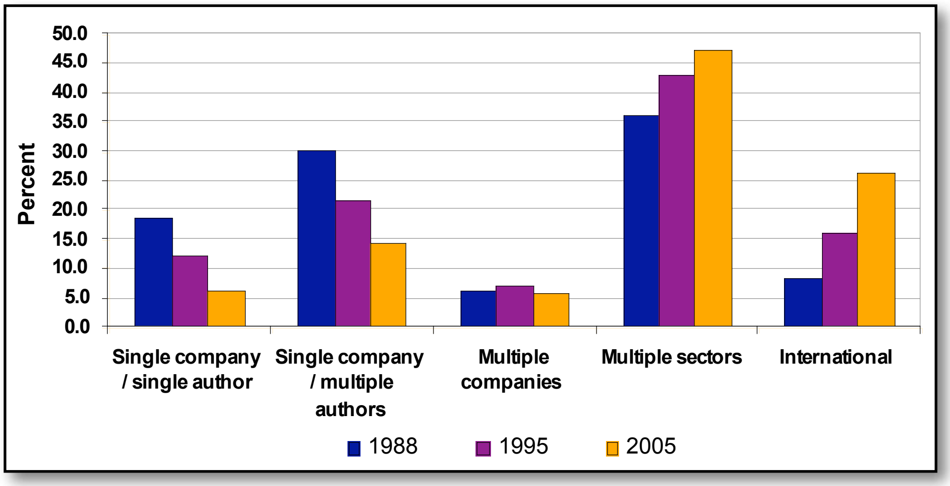
Research Publications[27]

Publication and citation of scientific results in peer-reviewed journals is one common metric for evaluating research outputs. Scientists and engineers in the EU authored or co-authored 33 percent of the world's S&E articles in 2005, followed by those working in the United States, who authored or co-authored 29 percent. While U.S. article output growth was relatively flat during the period 1995–2000, it again turned positive during the period 2000–2005, representing an annual average growth rate of 1.3 percent. China's continued high rates of S&E article production have enabled it to climb from fourteenth place in 1995 to fifth place in 2005. The United States remains the world leader in citations of S&E research articles.

The number of U.S. articles with co-authors by sector is a metric that can be used as an indicator of public-private research partnerships. Between 1995 and 2005, co-authorship in all U.S. sectors increased. In that same time period, industry co-authorship with academic institutions increased by 10.3 percent, the largest percentage point increase of all cross-sector co-authorships. These data also show that U.S. universities are forming additional international partnerships, which will continue to be an important opportunity as the R&D ecosystem becomes increasingly global.

The nature of published S&E articles by industry co-authors additionally reveals interesting trends of the R&D enterprise over the last 20 years. Between 1988 and 2005, both single company-single author publications and single company-multiple author publications decreased by almost 60 percent and 40 percent, respectively (see Figure 9). Conversely, multiple-sector publication collaboration increased by 70 percent, and international collaboration publications rose by over 300 percent. Collaborations between multiple companies remained stable over that time period, and represent a small percentage of all S&E articles by industry authors.

Figure 9. S&E articles with industry authors, by institutional author types, 1988, 1995, and 2005



Source: NSF S&E Indicators 2008

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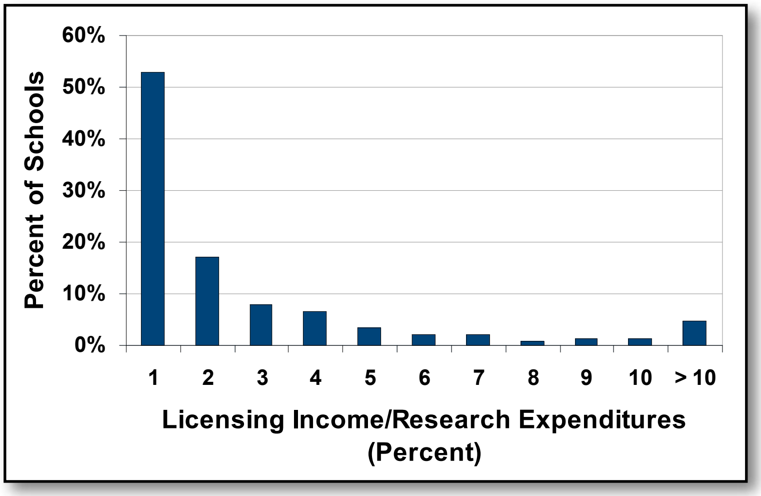
[27] All figures quoted in this section are from NSF S&E Indicators 2008.

Patents, Licensing Income, and Start-up Companies: Increased Focus by Universities

The efforts of universities to capitalize on IP in the form of patents and licensing, as well as the creation of start-up companies, can also be used as measures of outputs of R&D. The U.S. academic share of patenting by the private and non-profit sectors in the United States increased from under 2 percent in 1981 to a peak of almost 5 percent in the late 1990s, and has since dropped slightly to a level of about 4 percent in 2005. The actual number of patents granted to colleges and universities peaked at approximately 3,300 per year in 2002, and fell to around 2,700 in 2005.[28]

The successful commercialization of university research is largely dominated by a limited number of institutions.[29] As Figure 10 indicates, in FY2006, close to 80 percent of universities that responded to the Association of University Technology Managers' (AUTM) Licensing Survey saw licensing revenues of less than 3 percent of their total research expenditures.

Figure 10. Percent of Licensing Income to Research Expenditures, as reported by respondents to the AUTM Licensing Survey FY2006



Source: AUTM Licensing Survey FY2006

Finding significant trends on this subject is difficult, as AUTM data indicate a continuing growth in the number of invention *disclosures submitted* by university technology licensing offices, while the USPTO reports a recent decrease in the number of *patents granted*. Additionally, while a very useful source of information, AUTM data are not collected specifically for this type of analysis and are incomplete.

Furthermore, while most royalties from licensing agreements correlate to a limited number of patents held by a handful of universities, the timing of payments makes it difficult to assess overall trends in income from patenting. The median net royalties from academic patents has both risen and fallen over the last decade, climbing to $950,000 per university respondent in 2005 (Figure 11).

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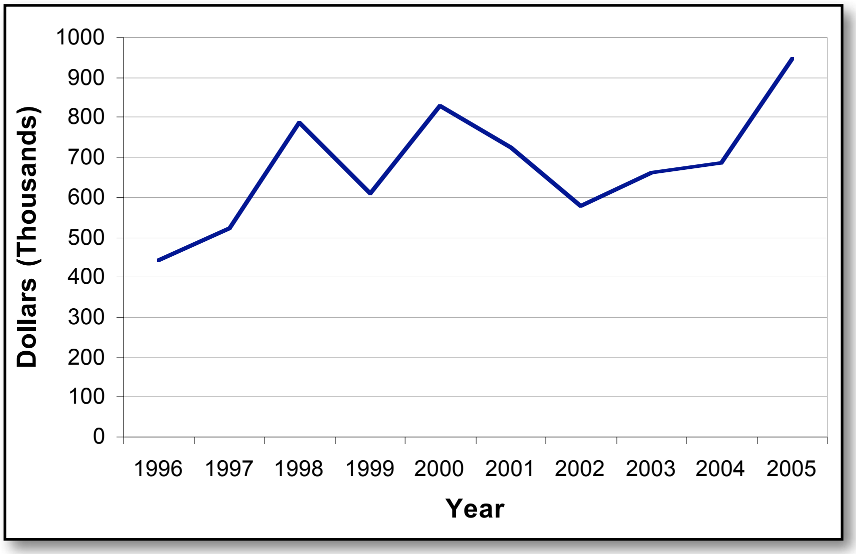
[28] NSF S&E Indicators 2008.

[29] Association of University Technology Managers' FY2006 Licensing Survey.

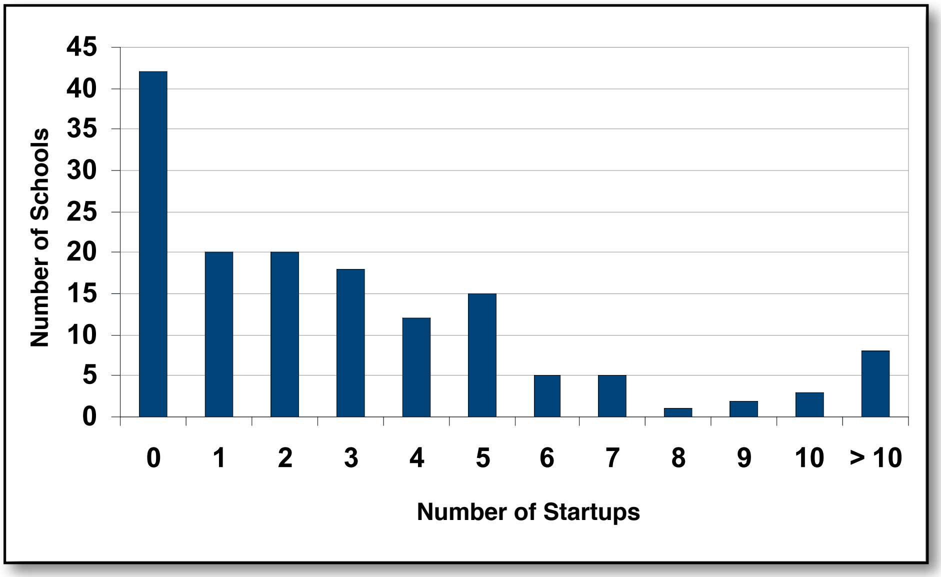
Figure 11. Median net royalties from academic patenting activities, 1996–2005



Source: NSF S&E Indicators 2008

The number of new start-up companies emerging from universities is also an important output measure, and some universities give it significant weight as they increasingly focus on regional economic development and job creation versus revenue. Over the period 1980–2005, universities and research institutions started 5,171 new companies, with over 400 of those being created in 2005 alone.[30] The majority of universities launch very few start-ups, however, as can be seen in Figure 12, in which the frequency of number of startups launched by school responding to the AUTM Licensing Survey is shown for FY2006.

Figure 12. Number of startups launched, as reported by schools responding to the FY2006 AUTM Licensing Survey



Source: AUTM Licensing Activity Survey Data, FY2006

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[30] Association of University Technology Managers' FY2006 Licensing Survey.

While each of the input and output measures presented in this section helps to depict certain aspects of the innovation ecosystem and university-private sector research partnerships, more robust metrics are needed to describe the actual inputs, outputs, outcomes, and impacts of the R&D enterprise. These improved measures will also have a direct impact on existing incentive structures, particularly at universities.

III. Findings and Recommendations

In completing this review of the innovation ecosystem and of several successful university-private sector partnerships, PCAST also reviewed elements from several previous studies. PCAST developed the following findings and recommendations to enhance innovation and address barriers for university-private sector research partnerships, which fall into five general areas:

1. Basic Research and Innovation
2. Economic and Regulatory Policies Impacting U.S. Innovation and Research Partnerships
3. Network Models of Open Innovation
4. Connection Points Between Partners in the Innovation Ecosystem
5. Measuring and Assessing Innovation

Basic Research and Innovation

Finding:

Universities continue to serve as a primary engine for discovery research that can lead to innovation and the Federal government remains the primary source to support basic research. While the diversity in sources of funding of the innovation ecosystem continues to expand, the Federal government remains the principle source of funding for basic research performed primarily at universities and the national laboratories.

Recommendation:

1. ***While exploring new partnership models and assessing the evolving innovation ecosystem, the essential role for the Federal government in supporting basic research must be recognized and maintained.***
   The nation has benefited tremendously by following the largely linear innovation model first proposed by Vannevar Bush in 1945. While the innovation ecosystem is increasingly perceived as less linear and more complex, the responsibility of the Federal government in maintaining a high level of basic research should continue to be recognized and upheld, even when making difficult decisions regarding funding priorities and exploring novel innovation processes.

Economic and Regulatory Policies Impacting U.S. Innovation and Research Partnerships

Finding:

The economic and regulatory environment impacting U.S. innovation and research partnerships requires significant long-term changes.
PCAST believes that recent economic and regulatory factors within the United States are exerting a significant negative impact on innovation. The U.S. economy has historically maintained a flexibility that can provide a global advantage, with the ability to quickly develop and apply new technologies and increase productivity. Increased constraints on an economy that is generally open with measured regulations threatens the ability of the United States to continue to compete in the global environment, a consequence that becomes even more critical in the current economic downturn. While economic impacts are being felt across the globe, U.S. economic and regulatory policies will play a critical positive or negative role in the nation's ability to recover.

Failure to Fully Utilize the R&D Tax Credit

At this stage the overall positive impact of the R&D credit appears to be generally recognized internationally, yet disagreements remain on the degree of this impact. Nevertheless, several countries have used R&D tax credits aggressively as one of many programs to enhance competitiveness and drive innovation.[31] According to the Organisation for Economic Co-operation and Development (OECD), the United States has not kept pace with other countries that offer tax subsidies. The United States provided the most generous tax treatment of R&D in the late 1980s among OECD nations, but by 2004 it had fallen to seventeenth place. While the United States has not made significant changes to the R&D tax credit, other OECD countries have implemented a number of policies to leverage this credit.[32]

Recommendation:

2. ***Update and enhance the R&D tax credit to make it a more stable and effective incentive for industry to perform and support R&D.***
   While continuing to support actions that would ensure greater permanency for this vital tax credit, PCAST also recommends other modifications to improve the credit. Congress should address elements of the credit that currently limit applicability and make it difficult for companies to plan their research and use the credit. These elements include adding flexibility in the time window for calculating the credit, expanding the credit rate, and generally providing more flexibility in how the credit is calculated and applied. Another issue raised in discussions with industry and private foundation leaders was that some research equipment and other research related infrastructure costs, such as overhead costs, may not be permitted in the calculation of the tax credit.[33] Providing increased incentives for supporting basic and discovery research versus more applied research could also stimulate support for higher risk innovative research programs. This change could provide an additional, very important incentive to further stimulate university-industry collaborations. The Administration should continue to work with Congress to implement comprehensive changes to the R&D tax credit.

Challenges with Technology Transfer Between Universities and the Private Sector

As described in the previous section, in a very broad sense technology transfer is critical to every stage of the innovation process. In general, PCAST finds the policies governing this system between university and industry to be reasonably effective; however, even extremely successful partnerships identified IP negotiations as a significant barrier and a continual challenge in the development of new partnerships. Ultimately, successful technology transfer negotiations often depend on individual efforts, particularly those of the leadership, from each organization having a strong desire to establish partnerships. In discussions with university and industry leaders, PCAST identified a number of potential barriers that can arise in the technology transfer process. These include IP negotiations as well as support for graduate students, publications, and other issues. Differences in interpretation and implementation of the Bayh-Dole Act, even among and within various universities or industries continues to be a challenge.

There is also debate concerning the changing roles and impacts of university technology transfer offices and university leaders in negotiating IP agreements. Various sectors of industry have criticized some universities for employing the same technology transfer approach for pharmaceutical- and biotechnology-related discoveries as they use for information technology inventions. Additionally, a university's approach to negotiating technology rights (such as a volume model instead of focusing on potential "homerun" technologies, or an income model) appears to have a significant impact on the formation of successful partnerships. Whatever the approach or strategy, the commitment to transparency, particularly from the private sector, is essential throughout the process.

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[31] Atkinson, R. Expanding the R&D Tax Credit to Drive Innovation, Competitiveness and Prosperity, The Information Technology and Innovation Foundation, April 2007

[32] OECD Main Science and Technology Indicators 2006

[33] Each country has its own definitions for costs that are eligible for tax incentives. The United States, for example, excludes overhead costs from the research base, but includes supplies. See: Rashkin, M. "Practical Guide to Research and Development Tax Incentives: Federal, State, and Foreign," CCH, 2007

Another obstacle often cited is the long "cycle time" required to work through negotiations. In most instances PCAST found that these potential barriers could be addressed if a few key factors were present, such as continued commitment from leadership, sufficient investment or the volume of research projects, significant interest from the principal investigators, transparency, frequent communications, and other factors. These factors are outlined in more detail later in this report.

Recommendation:

3. ***Develop guidance and educational tools on intellectual property and technology transfer practices for university and private sector partners.***
   The Department of Commerce, working in coordination with the National Science and Technology Council (NSTC), should develop guidance and educational tools to assist in the effective and efficient transfer of technology generated from Federally-funded research at universities to industry. These tools will foster shared principles between the communities. These documents and tools should be developed in consultation with representatives from academia and the private sector, including the venture capital community. Technology transfer officers and legal counsels are critical stakeholders in these negotiations and should be included in the development of any guidance. Existing documents, such as those developed by AUTM and the University Industry Demonstration Partnership (UIDP), should serve as a starting point for this process.

Tax exempt policies negatively impacting research collaborations

During this study, PCAST became aware of a potential barrier to developing research partnerships resulting from elements of the U.S. Tax Code and other policies that impact a university's tax-exempt status. One specific policy frequently raised is the Internal Revenue Service (IRS) Revenue Procedure 2007-47 (formerly 97-14)[34]. This procedure outlines the conditions under which universities may accept funding from the private sector to support research performed in research facilities built utilizing tax-exempt bonds. The IRS Revenue Procedure specifically defines requirements that universities must meet in order to maintain their status as a "safe harbor" and it limits pre-negotiations in assigning IP rights during the initiation of a collaboration. While the IRS has recently updated the procedure to address potential conflicts with the Bayh-Dole Act, the updated procedure continues to have different interpretations and presents a potential barrier to establishing partnerships. Several universities indicated that they have avoided using tax-exempt bonds in building facilities to circumvent any potential conflicts, while many universities are not able to pursue this option.

Recommendation:

4. ***Modify, or clarify through additional guidance, tax-exempt policies that may have an unintended negative impact on industry-supported research on university campuses.***
   PCAST recommends that the Department of Treasury, in coordination with the Office of Science and Technology Policy (OSTP), form a task force to assess these tax exemption issues, and to provide specific recommendations of policy options to the President, as appropriate. The work of the task force should include consultation with university and private-sector representatives. The work of the task force should be completed within a brief timeline of approximately six months.

Other Tax Policies that Impact Innovation

A range of other tax policies (including corporate tax rates, taxes on stock options, and other taxes) affects global competition and industry decisions on the location of manufacturing facilities. Tax breaks from China, for example, allow semiconductor firms to save one billion USD over ten years as they set up foundries outside the United States. The location of manufacturing facilities may, in turn, influence firm decisions to co-locate R&D laboratories near them. PCAST believes that large-scale relocations of R&D facilities outside the United States may have long-term implications for the nation's competitiveness.

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[34] Available at: http://www.irs.gov/pub/irs-drop/rp-07-47.pdf, accessed October 30, 2008.

Recommendation:

5. ***Develop a task force to assess other tax policies impacting innovation.***
   To further address these and other tax policies and their effect on innovation, PCAST recommends the President form a task force led by the Departments of Commerce and Treasury, and including others as appropriate. This recommendation was also made in PCAST's 2004 report *Sustaining the Nation's Innovation Ecosystems, Information Technology Manufacturing and Competitiveness.*[35] The goal of the proposed task force should be to assure that the United States returns to a competitive position among the community of nations with which it collaborates and competes; PCAST believes that current U.S. tax policies make the nation uncompetitive and that they are impacting its future global leadership. The task force should assess current tax policies impacting U.S. R&D innovation and competitiveness, including a comparison of foreign tax policies of major competitor countries. The task force should return to the President an assessment of current policies with a series of detailed recommendations, implementation actions and associated timelines.

The Role of Federal-State Coordination on Regional Economic Development

Enhancing Federal-State coordination in support of R&D innovation and alignment of economic policies has been a topic of previous PCAST activities[36] and these government partnerships continue to be a vital area of collaboration, particularly in the current economic environment. States have been very active in developing a range of programs to develop university-industry partnerships and also to promote economic development. While States can be viewed as having to compete with other States as well as other countries, areas of potential coordination and collaboration exist between States and the Federal government that can leverage programs and scarce resources more effectively. In this model, States will require Federal programs that are able to successfully compete by global standards.

Recommendation:

6. ***Assess mechanisms to enhance Federal-State coordination to promote innovation and university-private sector partnerships.***
   PCAST recommends that the President request a review of mechanisms to enhance Federal-State coordination of R&D policies designed to promote innovation and economic development. This review should include specific recommendations for enhancing coordination, while avoiding the creation of any new policies or organizations that would impact the autonomy or authorities of States and the Federal government. Organizations such as the National Governors Association should be involved to enhance coordination and communication across States. The National Academies' Government-University-Industry Research Roundtable should also be explored as a forum to develop a demonstration project to further enhance Federal-State coordination on R&D policies and economic competitiveness. The Departments of Commerce, Energy, and Education, along with NSF, the National Institutes of Health, OSTP, and other relevant agencies should participate in this activity.

Impact of Regulatory Burdens and Conflict of Interest Policies

While most regulations and policies governing issues such as conflict of interest were established to improve the quality and openness of research and research practices, PCAST has found that many university, government, and industry leaders believe they had an unintentionally negative impact on research and collaboration. This belief was especially common among university and government researchers, who often found research oversight and conflict of interest policies to be uncoordinated, confusing, and potentially leading to overregulation. In some cases, it was difficult to assess whether such situations were created by the policy itself or by its interpretation or implementation. Regardless, the problem does appear to be real, particularly at a time when there is a call for increased collaboration in multi-disciplinary work across various sectors in the government, academia and the private sector. This call for collaboration is juxtaposed with increased concerns over privacy, conflicts of

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[35] http://www.ostp.gov/pdf/finalpcastitmanuf_reportpackage.pdf, accessed October 30, 2008.

[36] http://www.ostp.gov/pdf/fed_state.pdf, accessed October 29, 2008.

interest, responsible conduct of research, and scientific openness. Indeed, there are currently calls from Congress for additional measures for NIH to monitor financial conflicts of interest. This is in spite of the fact that NIH now appears to have one of the most active and extensive Federal programs for oversight of conflict of interest issues.

Recommendation:

7. ***Assess options to streamline oversight structures and conflict of interest requirements while ensuring the accuracy and integrity of research and preserving the public's trust.***
   While striking a regulatory balance is continually difficult, the significant increase in regulations governing the research community (particularly in biomedical research) that are overseen by a range of agencies, combined with an increasing desire to seek collaborations within a diverse R&D community, creates a significant challenge. PCAST recommends that NSTC consider options for enhancing the coordination of relevant rules and regulations, through new structures and improved guidance, or by updating, modifying, streamlining, or consolidating regulations if necessary. The NSTC Research Business Models Subcommittee and Federal Demonstration Partnership are currently engaged in some of these activities, and they should be consulted on the most appropriate ways to implement this recommendation. This activity should involve significant agency and Congressional coordination and consultation with impacted communities from academia, the private sector, and the public.

Network Models of Open Innovation

Findings:

Open innovation has the potential to drive innovation in academia, the private sector, and government.

The changing paradigm from a linear innovation pathway to one more accurately described as a dynamic ecosystem highlights the many novel areas of input and collaboration that support innovation. Individuals and entire regions of the globe that would historically never interact can now collaborate on a research project in real-time. The private sector is increasingly utilizing this previously untapped resource to support their R&D efforts. These "open collaborations" or "open innovation" systems can be utilized to augment both corporations' existing internal R&D infrastructure and university collaborations. For some companies, such "distributed co-creation" could serve as a primary mechanism for new discoveries, while corporate research teams could then focus their attention on directed applications for new technologies.[37]

Over time, corporate R&D centers may tend to focus on incremental improvements to commercially successful technologies and thereby risk failing to position themselves to develop or identify disruptive innovations. Opportunities for mass collaboration provide a mechanism by which corporations may expand their R&D talent pool and seek rapid innovative solutions to their R&D questions. Companies such as InnoCentive and Proctor and Gamble, among others, have taken steps to harness mass collaboration in developing novel business models to drive innovation. Firms are developing different structures and approaches to utilize open innovation to address varied goals. This concept is too new to draw definitive conclusions about whether and how specific organizations should implement it. Additionally, not all challenges, such as IP ownership and the increased operational risks that will be faced in adopting such models, have been identified. Nonetheless, open innovation models have a number of elements that should be aggressively explored to utilize these extraordinary collaboration platforms. As a potential disruptive technology for promoting innovation, these platforms could be utilized by Federal agencies that fund or conduct research.

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[37] A number of books and articles discuss how companies are adopting open innovation. Four particularly useful sources are Prahalad, C. K. and Krishnan, M.S. *The New Age of Innovation: Driving Co-created Value through Global Networks*, McGraw-Hill, 2008; Chesbrough, H. *Open Innovation: The New Imperative for Creating and Profiting from Technology*, Boston: Harvard Business School Press, 2003; Chesbrough, H. *Open Business Models: How to Thrive in the New Innovation Landscape*, Boston: Harvard Business School Press, 2006; and von Hippel, E. *Democratizing Innovation*, Cambridge, MA: MIT Press, 2005

Open Innovation Models

PCAST has found that the approaches taken by InnoCentive and NineSigma, among other companies, have a tremendous potential for addressing challenging research questions. These platforms could have an amplifying effect by dramatically increasing the pool of individuals available to address a given question and decreasing the time to develop solutions, thereby ultimately decreasing the time to market.

Recommendation:

8. ***Further evaluate the impact and scalability of open innovation models.***
   The NSTC should initiate a project to further evaluate the impact of existing or emerging models of open collaboration to provide solutions to scientific and technical challenges. This should include assessments of the scalability of these platforms and the potential limitations inherent in the development and application of mass collaboration systems. The study should also explore opportunities and barriers (e.g., IP, mission conflicts, etc.) for universities and Federal agencies to participate in open collaboration platforms. The study would also include an assessment of the role for Federal agencies in leveraging these platforms by supporting or directly participating in open collaborations to address issues from developing advanced energy technologies to designing systems that support enhanced electronic medical records.

Targeted Prizes to Enhance Innovation

"Idea challenges" and various prize systems can serve as open innovations that complement a range of diverse approaches for innovation promotion. The use of inducement prizes and awards was prevalent in PCAST's study of research partnerships, and Federal agencies, industry, and foundations identified them as potential sources of some types of innovation. Such inducement prizes foster innovation to meet specific, future objectives. These objectives can pertain to many different stages of research, including basic research (for example, the Wolfskehl Prize to prove Fermat's Last Theorem and the Kavli prizes in the areas of neuroscience, cosmology, and nanoscience), applied research (for example, prizes in cryptography such as the Data Encryption Standard (DES) Challenges awarded for recovering the secret key used to DES-encrypt a plain-text message), and technology development (for example, the Defense Advanced Research Projects Agency (DARPA) Grand Challenge).

While the concept is not new – the use of inducement prizes to foster innovation spans nearly three centuries – there has been a renewed discussion regarding the use of prizes, and a growing number of foundations, government agencies, and private companies provide prizes of increasing size for developing solutions related to space travel, genetic sequencing, and energy efficiency, among others. The nature of the challenges and the significant awards offered by the X PRIZE Foundation have also renewed interest in the use of inducement prizes.

In 2006 Congress directed NSF to establish a prize program and the National Academy of Sciences recently released a report outlining a series of detailed recommendations for how to carry out such a program.[38] While this prize program must be balanced with NSF's primarily role and that of several other Federal funding agencies in supporting basic research through merit-based, investigator-initiated research utilizing competitive awards, PCAST identified the increased use of targeted prizes as a transformative element that can support innovation. While prizes impact innovation in a holistic manner and are not specific to university-private sector partnerships, successfully competing for innovation prizes will likely foster close collaboration between these communities.

Recommendation:

9. ***Federal agencies should expand the use of prizes to address certain challenging research questions.***
   As discussed above, NSF and other Federal agencies should further develop a prize based system to reward some types of innovation, and develop solutions to the most challenging research questions. PCAST recommends NSF work with OSTP to coordinate with agencies such as DARPA, NASA, DoE and others that also utilize various R&D prize programs. These efforts should carefully evaluate approaches and requirements for developing a productive prize system, through engaging industry organizations, the academic community, venture capitalists, and foundations, among others.

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[38] "Innovation Inducement Prizes at the National Science Foundation," Committee on the Design of an NSF Innovation Prize, National Research Council, National Academies Press (2007)

Connection Points Between Partners in the Innovation Ecosystem

Findings:

The connection points between partners in the innovation ecosystem need to be strengthened to reduce barriers to collaborations.

PCAST members continue to find that there is a need to strengthen connections between the various partners in the innovation ecosystem. Despite the increase in cross-sectoral collaboration seen over the past twenty years, there still appear to be substantial difficulties in forming such collaborations. Some of the barriers identified by PCAST include misalignment of cultures, management structures, and goals; and differences in IP, proprietary information, and publication policies. One critical element in this context is the fundamental difference in both time-lines and motivations for industry and universities. Particularly in the current economic environment, corporations and their shareholders are focused on short-term returns. Long-term research programs that can lead to technology innovations often require significant investments and run counter to this philosophy. While not attempting to fundamentally change this business model, it is critical for potential partners to understand and acknowledge these forces and plan accordingly early in the process.

Many novel approaches are being pursued to turn the connection points into opportunities. For example, the UIDP[39] is developing a software tool to streamline the negotiation of IP clauses in collaborative research agreements. After learning directly from companies that dealing with the university was very cumbersome, the Medical School at the University of Pennsylvania established a central Office of Corporate Alliances that creates a "one-stop shop" for managing partnerships between faculty members and outside sponsors, reducing administrative burdens and regulatory concerns for both sides. The office also works with both sides to define broad areas of interest and expertise, to build strategic, long-term alliances rather than individual sponsored research agreements. The Energy Biosciences Institute is pursuing a novel hybrid approach towards public-private partnerships that co-locates both open and proprietary research, allowing fundamental science results to be shared by all, while BP can initiate proprietary work inspired by such research. Others, such as Intel's Lablets, encourage cross-sectoral sabbaticals for faculty and researchers in industry. Further strengthening of the connection points will be crucial for increasing the participation in public-private partnerships.

Key Elements/Guiding Principles to enhance research partnerships

Given the diversity of ways in which partnerships occur, it is clear that there is no "one size fits all" approach to strengthening connection points between partners. However, there is consensus on some key elements, or guiding principles, that have been found to minimize barriers to successful partnerships. A detailed list of these principles, based on PCAST's experiences and those provided by several presenters, are included in Appendix A and B.

Recommendation:

10. ***Build on existing frameworks of successful university, government, and private sector initiatives to enhance research partnerships.***
    Several organizations have been formed in recent years to better understand, and provide options to overcome, the barriers that can prevent successful public-private partnerships. The UIDP is a cross-sectoral group that works on developing new approaches to collaborative arrangements and generally encourages long term university-industry relationships. Both the National Academies' Government-University-Industry Research Roundtable (GUIRR) and the Business Higher Education Forum (BHEF) have published several reports on the connection points between public and private collaborators. The frameworks developed by these groups and others should be built upon to better understand how to optimize the interface between various actors. Indeed, NSF has recently initiated a series of workshops to enhance university-industry partnerships to promote the discovery to innovation process. Building on these efforts, NSF and Department of Commerce should develop a set of principles to guide these efforts.

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[39] http://uidp.org, accessed October 30, 2008.

Role for exchange of human capital in creating a productive innovation environment
One experience that seemed common across all the successful partnerships studied by PCAST was the cross-fertilization of individuals with experience in the government, academic, or industrial sectors. Exchanging personnel increases mutual understanding of organizational missions, abilities, and constraints and generally builds trust between partners, a prerequisite for formalized partnerships. Co-location of industrial facilities and universities appears to enhance the exchange of human capital and provide for flexible arrangements. This exchange is especially important for young professionals who are often the drivers of new innovation.

Recommendation:

11. ***Formalize and enhance opportunities and incentives for researchers to have flexibility in moving between academia, industry, and government.***
    Decision makers in academia, industry, and government should examine their organization's mechanisms available for researchers to move between sectors, and work to formalize and enhance them when appropriate. Incentives to reward collaboration and encourage teamwork should be offered. Carnegie Mellon University, for example, has allowed faculty members to take extended sabbaticals to serve as co-directors of Intel's Lablets, so that they can build relationships with industry partners while remaining a part of the academic community. Developing mechanisms to allow flexible exchange of researchers will promote the participation in cross-sectoral partnerships. For example, academic institutions could provide flexibility in the tenure process to acknowledge the importance and time commitment required to pursue these opportunities. These activities can support the mission of the university by both generating new knowledge, increasing professional development of faculty and ultimately enhancing the training of students via faculty who can share these experiences.

    Federal R&D funding agencies should continue to explore options, through grants and various fellowships, to provide flexibility for researches to engage in sabbaticals and career transitions across academia, government and the private sectors. The Federal government should develop hiring practices and rewards that promote this flexibility within Federal agencies and develop policies to encourage universities to support these career paths among their faculty. Early career scientists and engineers should be specifically targeted through such programs, to both fully utilize their innovative potential and to provide an early opportunity that will provide benefits throughout their careers. These practices can also be integrated into the structure of Federally funded university research centers/programs such as NSF's Engineering Research Centers, NSF Science and Technology Centers, the NIH's Clinical and Translational Science Awards, the NIH National Cancer Institute designated Cancer Centers and other large university research centers and programs funded through Federal agencies.

Measuring and Assessing Innovation

Finding:

Enhanced tools and metrics for policy makers and research partners to ultimately assess the outputs of the innovation system and the demands of the individual partners (both technology and workforce) are lacking.
Despite continued concerns about the competitiveness of the United States in a number of areas from S&E education and workforce to technology development and commercialization, PCAST found that there are few robust measures and quantitative assessments to validate these conclusions with high confidence. While there have been measured advances in data collection, these are often on the inputs to the innovation system and less focus has been placed on measuring the outputs. Developing meaningful output measures for innovation remains a challenging area of research. In order to accurately develop effective interventions to enhance the innovation system, more robust metrics should continue to be developed to assess both outputs in terms of knowledge, technologies and intellectual capital/workforce, as well to understand the demands from the various partners, including the government and the private sector. These measures will also be critical to determine what change, if any, may result from a given intervention and how the ecosystem responds from a holistic perspective. The Secretary of Commerce's Advisory Committee on Measuring Innovation in the 21st Century Economy recently released a report entitled "Innovation Measurement" in which they set forth a number of recommendations for

developing metrics to accurately measure the performance of the innovation ecosystem.[40] A continuing challenge in measuring productivity will be identifying where it is appropriate to recognize activities that are short-term versus long-term. Setting the appropriate time-lines will be essential to recognize when short-term productivity can be improved, while continuing to build long-term research capacity.

Additionally, the current metrics that govern the incentives and rewards system lack the flexibility to optimally support university-private sector research partnerships and innovation. Current metrics to evaluate the success of university researchers and determine tenure decisions are limited primarily to publications and Federal grants and often fail to recognize other critical factors. As mentioned previously, this is also true for some university technology transfer offices that may be assessed primarily on revenue generated versus value-added or volume of products and knowledge that is moved out of the university.

Recommendation:

12. ***Develop and apply improved tools and metrics to measure the outputs of research partnerships and innovation to guide policies and incentive structures.***
    Federal R&D funding agencies, in coordination with statistical analysis agencies (Bureau of Economic Analysis and others), should further develop tools and metrics to assess the products and outputs of targeted research collaborations. These measures could be integrated into appropriate funding program requirements and include measurements to assess:

    a. Technology innovation

    b. Workforce- human capital- capacity building

    c. Productivity

    Using the competitiveness and innovation priorities identified in the American Competitiveness Initiative, a program should be initiated to more clearly define national and industry demands for technology innovation in these areas and the type and size of S&E workforce required to meet these demands.

    NSTC and NSF's Science of Science and Innovation Policy program are exploring a number of issues related to these challenges and should be leveraged (with the Department of Commerce, Bureau of Economic Analysis and the Bureau of Labor Statistics, for example) and expanded, where appropriate.

    Federal R&D funding agencies should also evaluate and implement strategies to expand and add flexibility to the metrics that govern the current incentive system, including those utilized by universities. This could be integrated into research center/program grants by providing incentives for industry participation, entrepreneurship activities and fostering State and local involvement. To provide flexibility for a range of university programs strong incentives should be provided for these components without strict requirements for all elements. Updated innovation measures should then be used to further guide the modification and transparency of incentive systems, permitting enhanced research partnerships.

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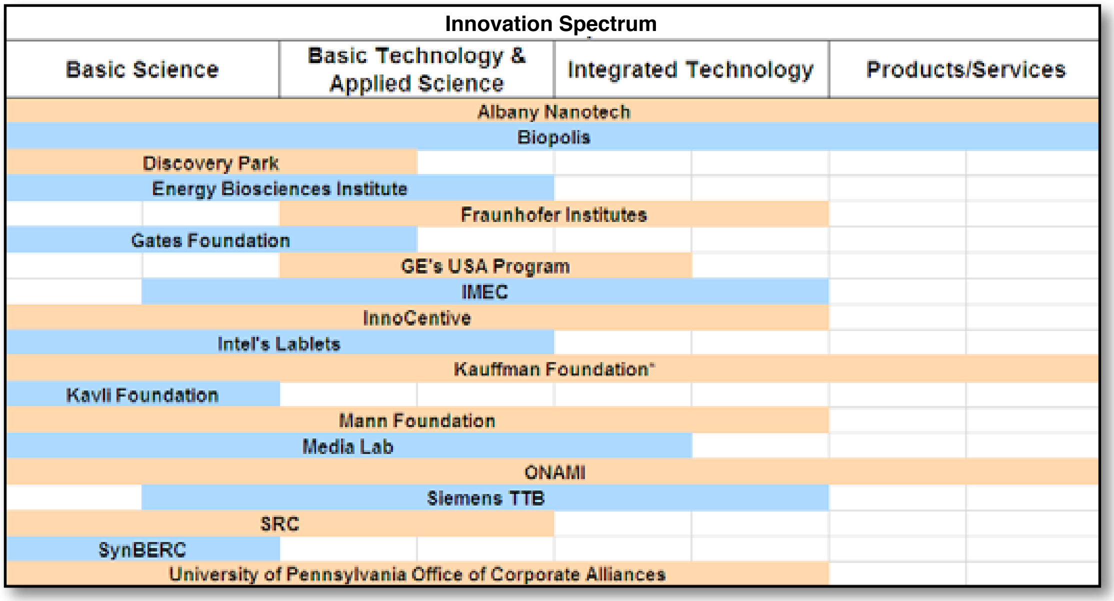
[40] See: http://www.innovationmetrics.gov/, accessed November 7, 2008.

Appendix A: Review of University-Private Sector Research Partnerships and Organizations that Support Partnerships

As described in the main text, university-private sector research partnerships are one vital element of the U.S. innovation ecosystem. PCAST finds these partnerships especially important given long-term Federal funding trends and increased global competition. PCAST initiated a study to identify approaches to stimulate interactions between the private sector and universities and this report provides the key findings and recommendations that emerged from the study. Part of this study involved examining several successful partnerships – U.S.-based as well as international – between universities and the private sector. These partnerships vary greatly in size, scope, focus, and length.

This appendix contains profiles of public-private partnerships (PPPs), foundations that fund PPPs, and other organizations that support university-industry collaboration. These profiles highlight the variety seen across, and even within, various models. For a number of the partnerships listed PCAST heard directly from executives involved in establishing or currently overseeing the activity. This section includes several approaches to examining these collaborations, including the formality of the partnerships and the location they fall in linearized model of the innovation spectrum (Figure 13). These examples represent a diverse set of partnerships, and not surprisingly no one model emerges as the ideal structure. Developing "best practices" to guide the development of these arrangements would also prove difficult and potentially misleading, but PCAST did observe a number of elements that emerged from assessing the partnerships and these are outlined in more detail in Figure 14.

Figure 13. Public-Private Partnerships, and selected foundations and other organizations that support partnerships, are described below, along with locations on the innovation spectrum



<table>
<tr><th colspan="8">Innovation Spectrum</th></tr>
<tr><th colspan="2">Basic Science</th><th colspan="2">Basic Technology & Applied Science</th><th colspan="2">Integrated Technology</th><th colspan="2">Products/Services</th></tr>
<tr><td colspan="8">Albany Nanotech</td></tr>
<tr><td colspan="8">Biopolis</td></tr>
<tr><td colspan="3">Discovery Park</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Energy Biosciences Institute</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="4">Fraunhofer Institutes</td><td></td><td></td></tr>
<tr><td colspan="3">Gates Foundation</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="3">GE's USA Program</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="5">IMEC</td><td></td><td></td></tr>
<tr><td colspan="6">InnoCentive</td><td></td><td></td></tr>
<tr><td colspan="4">Intel's Lablets</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8">Kauffman Foundation*</td></tr>
<tr><td colspan="2">Kavli Foundation</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Mann Foundation</td><td></td><td></td></tr>
<tr><td colspan="5">Media Lab</td><td></td><td></td><td></td></tr>
<tr><td colspan="8">ONAMI</td></tr>
<tr><td></td><td colspan="5">Siemens TTB</td><td></td><td></td></tr>
<tr><td colspan="4">SRC</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">SynBERC</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">University of Pennsylvania Office of Corporate Alliances</td><td></td><td></td></tr>
</table>

**The Kauffman Foundation funds research on the innovation spectrum itself*

Figure 14. Themes observed from Public-Private Partnerships

PCAST Themes								
Public-Private Partnerships (PPPs)	**Targets a Specific Field, Technology, or Particular Area on Innovation Continuum**	**Develops Strategic Partner-ships**	**Utilizes a Consortia Model**	**Substantially Leverages Government Funding (State or Local)**	**Focuses on Open Collaboration**	**Provides Flexible or Novel Approaches to Address Technology Transfer**	**Links R&D, Education, Entrepreneurship, and/or Innovation**	**Establishes Clusters to Promote Innovation**
Albany CNSE	X	X		X		X	X	X
Biopolis and Fusionopolis	X	X	X	X		X	X	X
Discovery Park	X			X		X	X	X
Energy Biosciences Institute	X	X	X	X	X	X	X	
Fraunhofer Institutes	X	X	X	X		X	X	X
GE's USA Program	X	X					X	
IMEC	X	X	X	X		X	X	
Intel's Lablets	X	X			X	X	X	X
Media Lab	X	X	X		X	X	X	
ONAMI	X	X	X	X		X	X	X
Siemens TTB	X	X			X	X	X	
SynBERC	X	X	X	X			X	
SRC	X	X	X	X	X		X	
UPenn OCA	X	X				X		
Foundations that Support PPPs:								
Gates Foundation	X			X				
Kaufmann Foundation	X							
Kavli Foundation	X	X						
Mann Foundation	X	X						

College of Nanoscale Science and Engineering's Albany Nanotech Complex

Overview/goals

- The College of Nanoscale Science and Engineering (CNSE) at the State University of New York (SUNY) Albany is dedicated to education, R&D, and deployment in the emerging disciplines of nanoscience, nanoengineering, nanobioscience, and nanoeconomics.
- CNSE's Albany NanoTech Complex is a 800,000-square-foot R&D enterprise that attracts nanoelectronics companies and organizations.

Institutions and partners involved

- The State of New York; more than 250 global corporate partners, including IBM, AMD, SEMATECH, among others; Federal government laboratories and agencies, including NIST; numerous universities, including Harvard, Yale, MIT, Georgia Tech, among others; hundreds of small- and medium-sized businesses supplying high-tech products, materials and services; dozens of school districts implementing K-12 nanoscale educational initiatives; numerous economic development agencies and community outreach organizations.

Duration of partnership

- Partnerships range from long-term (in excess of 10 years) R&D consortia to medium- and short-term (six months to three years) programs developed individually between CNSE and global corporate/academic partners.

Specific science or technology focus, including area on the innovation spectrum

- Nanoscience, Nanoengineering, Nanoeconomics, and Nanobioscience focusing on nanotechnology convergence and multi-functional devices for computation, energy, defense, biomedical, communications and transportation applications.
- Education and research span the innovation spectrum of nanoscale technologies, from fundamental research to leading-edge development to commercialization.

Characteristics of partners

- Global corporate partners include small, medium, and large high-tech companies that represent the entire supply chain fueling the nanotechnology industry. Partners span biomedical, energy, environmental, defense, transportation, telecommunications and consumer sectors.
- NanoTech Complex employment of scientists, researchers, engineers, technicians, faculty, and students has grown from 72 in 2001 to 2,200 in 2008, and is projected to exceed 2,500 by mid-2009.

Distribution of activity

- CNSE's Albany NanoTech Complex is primary location of R&D activity.

Characteristics of funding

- Current investment is more than $4.5 billion, of which approximately 75 percent represents private funding and 25 percent is public funding.
- CNSE's Albany NanoTech Complex grew out of New York's Center of Excellence in Nanoelectronics and Nanotechnology, founded in 2001 with $50 million from the State of NY and $100 million from IBM.

Approach to technology transfer

- CNSE has developed a customized business paradigm that allows companies to access technology, infrastructure, and intellectual capital specific to the needs of their organization.

- Technology transfer arrangements could also be negotiated upfront as part of cross-licensing agreements within vertically integrated consortia.

Education and training component

- CNSE grants doctoral and master's degrees in nanoscale science or nanoscale engineering. A dual-degree "Nano+MBA" is also offered, leading to a MS in nanoscale science or engineering and an MBA.
- Numerous workforce training partnerships with four-year and community colleges.
- A number of educational and workforce development initiatives for high tech trades training, such as a partnership with M+W Zander, supported by funding from the New York Assembly, to train union members in operation and maintenance of cleanroom facilities and advanced equipment.
- Large number of partnerships with K-12 school districts to present innovative nanoscale education programs.

Website

- http://cnse.albany.edu/

Biopolis and Fusionopolis

Overview/goals

- A*STAR's Biomedical Research Council (BMRC) supports, oversees and coordinates public sector biomedical R&D activities in Singapore. The locations of these activities are centered around Biopolis and Fusionopolis.
- Biopolis includes seven research institutes, six research consortia and centers with basic and translational research capabilities in the area of biological sciences, while Fusionopolis, currently under development, will focus on physical sciences and engineering research capabilities broadly aligned to the major industry sectors in Singapore.

Institutions and partners involved

- Several key Singapore government agencies; publicly-funded research institutes, and R&D labs of pharmaceutical and biotech companies. A*STAR works in close partnership with the Ministry of Health through the Biomedical Sciences (BMS) Executive Committee in the national effort to drive translational and clinical research to bring scientific discoveries from the bench to the bedside, and ultimately improve human health and healthcare delivery.

Duration of partnership

- Semi-permanent

Specific science or technology focus, including area on the innovation spectrum

- Biopolis supports research programs in genomics, molecular and cell biology, bioengineering and nanotechnology, medical biology, and clinical and translational research. It focuses on the entire chain of biomedical sciences activities – from R&D to manufacturing and healthcare.
- Fusionopolis focuses on physical sciences and engineering, with a spectrum of capabilities ranging from data storage to microelectronics, computational science, manufacturing technology, materials science & engineering, information and communications research, and chemical sciences.

Characteristics of partners

- Biopolis is home to 2,000 scientists, researchers, technicians and administrators. Fusionopolis will be home to over 2,000 scientists, engineers and administrators by 2012.

Distribution of activity

- Researchers live and work in Biopolis and Fusionopolis; Research facilities are shared by residents of Biopolis.
- Biopolis is located close to the National University of Singapore, the Singapore Polytechnic, the Institute of Technical Education, the National University Hospital, the Singapore Science Park, Ministry of Education, and Fusionopolis, a complementary facility focusing on physical sciences and engineering.

Characteristics of funding

- Officially launched in 2003, Biopolis was developed and completed by the government of Singapore at a cost of $500 million.
- Phase 1 of Fusionopolis, which costs $600m to develop will officially open in October 2008. Besides the public and corporate labs, and government agencies, it will also house serviced apartments, retail shops, sports facilities, and food and beverage outlets.

Approach to technology transfer

- Exploit Technologies Pte Ltd (ETPL), A*STAR's strategic marketing and commercialization arm, manages and consolidates the intellectual properties of A*STAR's research institutes and enhances the research output of its scientists by translating their inventions into marketable products or processes through licensing deals and spin-offs with industry partners.

- Eighteen leading institutions in Singapore, the United States, Canada, Europe and New Zealand have joined the global Technology Transfer Network (TTN) to bolster the commercialization of IP assets. The TTN, with the HQ in Singapore and hosted by A*STAR, was launched in February 2008 with eight founding members through an A*STAR-led initiative. The TTN is a collaborative alliance of technology transfer offices formed to enhance the effectiveness of technology transfer to industry. The core activities of the TTN include IP cluster mapping, training and certification of TTO professionals, joint marketing and events, technology advisory services, industry collaboration, and regular dialogue and sharing of best practices.

Education and training component

- The A*STAR Graduate Academy (A*GA) promotes science scholarships and other manpower development programs and initiatives.
- A*STAR aims to train 1,000 Singaporean PhD candidates by 2015.
- A*STAR provides awards to top local and foreign talent through its Science Awards and the Young Researchers Attachment Programme. The National Science Scholarship targets top students from the various Junior Colleges for full support from BS to PhD levels at leading overseas universities.

Website

- http://www.a-star.edu.sg/

Purdue Discovery Park

Overview/goals

- Discovery Park is designed to foster large-scale interdisciplinary research and learning programs at Purdue University. It is designed to foster fast, speedy responses to research opportunities. Discovery Park facilitates relationships within the University as well as with external entities such as corporations and its goal is to translate research developments into economic development progress in Indiana and beyond.

Institutions and partners involved

- Purdue University; State of Indiana; Lilly Endowment; Mann Foundation; Regenstrief Foundation; Kauffman Foundation; Burton Morgan Foundation; Indiana University School of Medicine; Mayo Clinic; numerous other universities, corporations, foundations and institutions.

Duration of partnership

- Project-specific time length

Specific science or technology focus, including area on the innovation spectrum

- Research takes place in eleven centers, focusing on: Advanced Manufacturing, Bioscience, Cyber, e-Enterprise, Energy, Entrepreneurship, Environment, Healthcare Engineering, Learning, Nanotechnology, and Oncology.
- The Entrepreneurship Center works with the Purdue Research Park to launch businesses based on the basic and applied research taking place in other centers of Discovery Park.

Characteristics of partners

- Over 1,000 Purdue faculty members are affiliated with the Park, hundreds of graduate students and over 3000 undergraduate students have been involved in programs to date.
- More than 100 significant company or corporate partners work with researchers at Discovery Park.

Distribution of activity

- Discovery Park activities take place in five buildings built on forty acres on Purdue's campus, with additional activities distributed throughout campus.
- Companies may have access to lab facilities; private lab space can be leased by companies.
- Successful R&D projects can be continued by private companies in Purdue Research Park.

Characteristics of funding

- In 2001, Lilly Endowment granted $26 million for the first four centers; another $25 million was granted in 2004. Additional funding was granted from the Burton Morgan Foundation, the Kauffman Foundation, the Regenstrief Foundation and other generous donors.
- Discovery Park is a $400 million research enterprise. With $200 million in new facilities, equipment and laboratories, the park and its 11 major centers has generated $74 million in sponsored research in the 2007-2008 fiscal year.

Approach to technology transfer

- Discovery Park shares staff with the Office of Technology Commercialization at the Purdue Research Foundation. The goals are to work individually with faculty, identify promising technology, and expedite the commercialization process.

Education and training component

- The Undergraduate Certificate in Entrepreneurship and Innovation program inspires and teaches students in all disciplines to be innovators and entrepreneurs.
- The Technology Realization Program aims to help graduate students understand the challenges of managing the development and introduction of new ideas/technologies along with starting and managing new business ventures.
- Internship programs for undergraduates at both Discovery Park and in start-up companies.

Systems to reward involvement in partnerships

- There are several benefits offered to Discovery Park partners, including: access to several seed grant programs; access to exceptional research equipment; and administrative and technical support for development of large scale grants.
- Discovery Park's leadership facilitates the recognition of faculty involvement in interdisciplinary research in tenure and promotion decisions.
- The Entrepreneurial Leadership Academy develops an entrepreneurship community among faculty for purposes of networking, brainstorming and discussing Purdue entrepreneurial curricula and activities.

Website

- http://www.purdue.edu/dp/

Energy Biosciences Institute

Overview/goals

- The Energy Biosciences Institute (EBI) is an R&D organization designed to explore the range of applications of biology to the energy sector and to create a new discipline of Energy Biosciences.

Institutions and partners involved

- University of California at Berkeley (UCB); Lawrence Berkeley National Lab (LBNL); the University of Illinois at Urbana-Champaign (UIUC); and BP

Duration of partnership

- BP supports the EBI through a 10 year contract.

Specific science or technology focus, including area on the innovation spectrum

- Current research is focused on the areas of feedstock development, biomass depolymerization, biofuels production, fossil fuel bioprocessing, and environmental, social, and economic dimensions of biofuel adoption.
- EBI's portfolio ranges from basic research to applied proprietary projects for commercial applications.

Characteristics of partners

- UCB employs nearly 1,500 full-time faculty members, 9,000 graduate students and about 1,200 post-doctoral fellows. LBL has a staff that numbers about 4,000, including more than 800 graduate and undergraduate students. UIUC has more than 11,000 graduate students and nearly 3,000 faculty members.
- BP employs more than 100,000 people worldwide and more than 35,000 in the United States.

Distribution of activity

- An EBI building will be built on the UCB campus. The EBI is housed in the Institute for Genomic Biology on the UIUC campus. BP will eventually place approximately 50 scientists and technologists on the campuses of UCB and UIUC to work with the academic researchers.
- The co-location of researchers from all participants is an important aspect of the partnership.
- Open and proprietary research are co-located, allowing for efficient technology transfer

Characteristics of funding

- BP will provide $500 million to EBI over a ten-year period.
- Infrastructure investment was added by the states of California and Illinois.

Approach to technology transfer

- IP agreements have been developed to satisfy both industrial and academic needs. Research collaborator inventions will be owned solely by the research collaborator whose employees or contractors are inventors defined by policies applicable to those employees. BP invention will be owned solely by BP and joint inventions will be jointly owned. BP will have a nonexclusive royalty free license to IP generated out of the academic work. BP also has an option to negotiate for an exclusive license if desired.
- Publication policies followed a process of an initial review period of thirty days that BP can review the proposed publication. If there is patentable material within the publication it can be delayed up to an additional 60 days. BP will attempt to complete an urgent review if publication may be imminent.

Education and training component

- EBI offers programs that prepare undergraduate, graduate and post-doctoral students in the biological sciences, chemistry, engineering, and socio-economic sciences to bring novel approaches to solving global energy challenges.

Website

- http://www.energybiosciencesinstitute.org/

Fraunhofer Institutes

Overview/goals

- Fraunhofer Gessellschaft (FhG) is one of Germany’s four non-university research organizations.
- FhG has 56 institutes in Germany in 40 different locations, and has research units in the United States and Europe. Representative offices, with no research units, are located in the Middle East and Asia.
- The Fraunhofer Institutes are designed to conduct applied research with the aim of enhancing the innovative capacity of German industry. All Fraunhofer activities have the goal to develop, transfer and introduce new technologies into the market.

Institutions and partners involved

- German government; German state governments; private companies.

Duration of partnership

- Permanent institutions

Specific science or technology focus, including area on the innovation spectrum

- The Fraunhofer Institutes are grouped into seven research alliances (called Fraunhofer Groups): Defense and Security, Information and Communication Technology, Life Sciences, Materials and Components, Microelectronics, Production and Surface Technology and Photonics.
- Fraunhofer Institutes perform both pre-competitive research and contract research for specific companies.

Distribution of activity

- Fraunhofer recognizes the importance of innovation clusters. They note that knowledge-based industries thrive in environments in which they are regionally clustered, leading to knowledge exchange and a critical mass of skills.

Characteristics of funding

- Program-level funds are allocated based on the level of funding obtained from industry or other users. The Institutes are expected to solicit 2/3 of their funding from industry or other sources, and they receive a corresponding amount of funding from the German government.
- Currently, approximately two thirds of the Institutes’ €1.3 billion annual research budget comes from contract research performed on behalf of industry and the government. The remaining fraction of the budget comes from both Federal and State governments in the form of institutional funding.

Approach to technology transfer

- Although many Institutes have a special marketing and/or business development department, all leading researchers at Fraunhofer are expected and able to find customers for Fraunhofer technologies. The institutes, therefore, do not have specific technology transfer offices.
- Access to and in some cases ownership of IP is granted to industry partners based on the resources those partners contribute to center based R&D.

Education and training component

- Fraunhofer Institutes comprise research faculty and research staff, neither of which have tandem appointments in academic departments, though interactions occur with universities since many Fraunhofers are adjacent to university campuses.

Systems to reward involvement in partnerships

- 90 percent of the Institute Directors are full professors at local universities (dual appointment), and some department heads have lecturer or adjunct professor positions at universities. Many Fraunhofer researchers have appointments at local universities as well.

Website

- http://www.fraunhofer.de/EN/

General Electric's University Strategic Alliance Program

Overview/goals

- General Electric's (GE) University Strategic Alliance (USA) Program is a joint research venture between engineers in GE Aircraft Engines program and university researchers and graduate students.

Institutions and partners involved

- The program involves eight universities in the United States, Europe and China.

Duration of partnership

- The program guarantees 3 years of funding, renewed on a rolling basis.
- **Specific science or technology focus, including area on the innovation spectrum**
- Research areas are those of critical technical importance to GE's business needs, including Turbine Cooling and Heat Transfer, Aeromechanics, Compression Aerodynamics, Advanced Manufacturing Processes, Computational Fluid Dynamics.

Characteristics of partners

- More than 50 professors and graduate students working on 14 separate research projects.

Distribution of activity

- The university performs the work with strong interaction with GE engineers.

Characteristics of funding

- Funding for individual programs range from $25,000 to over $500,000.

Approach to technology transfer

- GE and the partnering universities have developed IP policies for work developed through the USA program. GE will not pay royalties, but will consider license fees. In the case of joint invention, patents will be jointly owned. In the case of gas turbines, GE retains exclusivity. GE encourages publication, provided that proprietary information is protected. Usually this entails waiting until a patent application is filed before submitting work for publication. GE has review rights; reviews are prompt and clear. GE has acknowledged that IP rights in other countries such as China are more favorable for industry investments than they are in the United States.

Education and training component

- Graduate students benefit from interacting with industry scientists on R&D projects.

Systems to reward involvement in partnerships

- GE actively recruits the graduate students involved in USA research. In some cases, faculty involved are more likely to be approached when opportunities for externally funded (NASA, DOD, etc.) joint research arise.
- To encourage participation in the partnership, GE provides full financial support to graduate students in the USA program, even in the event of program termination.

IMEC

Overview/goals

- IMEC is a non-profit company, founded by the state government of Flanders in Belgium. The overall goal for IMEC is to perform next generation electronics R&D ahead of industrial needs by three to ten years.

Institutions and partners involved

- IMEC collaborates with more than 500 industrial partners, totaling nearly 1,000 partners, including a university partnership of more than 200 and some 100 research institutes worldwide.
- IMEC's associated labs are at Ghent University, the University of Brussels and the University of Hasselt. IMEC also collaborates with other universities in Flanders, such as the Catholic University of Leuven and the University of Antwerp.

Duration of partnership

- IMEC is a permanent institution. Industrial partnerships usually are for a multi-year duration, typically 3 years or longer. Short-term partnerships typically are more narrowly-defined, and are often more focused on the development phase of the technology life cycle.

Specific science or technology focus, including area on the innovation spectrum

- Research areas include: nanoelectronics and nanotechnology design, methods, and technologies for Information and Communications Technology systems.
- IMEC engages in research on many points on the innovation continuum, from basic or embryonic research to proprietary technology development. Typically, IMEC performs R&D in domains and on topics that have a view on commercialization.

Characteristics of partners

- A significant amount of research is also supported by Flemish and European co-funding programs. In these consortium programs, partners are part of a consortium, like IMEC, the latter often being the coordinator of the program.
- Industrial partners represent all sizes of corporations, from very small SMEs (1-10 people), typically to do more development oriented work, to very large (e.g. Intel, Texas Instruments, Samsung), typically to undertake large very advanced joint research programs.

Distribution of activity

- IMEC has a central lab located in Leuven, Belgium, and affiliated labs located throughout Flanders. In addition, it has a daughter R&D center in Eindhoven, The Netherlands. IMEC-NL is a joint venture with TNO (NL) forming together the Holst Centre. IMEC provides infrastructure and resources to support 1,400 visiting researchers including 500 researchers from industry partners.

Characteristics of funding

- Includes funding from international industry (over 50 percent), Flemish industry (about 20 percent), European Community, and the European Space Agency, and an annual grant from the Flemish Government (about 40 million, or 16 percent of the total budget). The grant is part of a 5-year renewable management agreement with the State Government of Flanders including a number of key performance indicators (scientific output, business generation, regional impact, etc).
- In 2007, IMEC's total budget was EUR 244.5 million.

Approach to technology transfer

- In some cases results are owned exclusively by IMEC and are available for licensing, providing full user rights for the industrial partner. In other cases, some expertise is co-owned by both IMEC and the industrial partner without any accounting to each other. Company-specific results or confidential information is under exclusive ownership of the industrial partner. In this case the industrial partner gets access to IMEC's background information in the research domain specific to the project and the other results of the other industrial partners in the same project.

Education and training component

- Students work in cooperation with industry researchers on projects arranged by academic faculty from their home university engineering departments.
- IMEC also provides training to industry, universities and institutes through its microelectronics training center.
- IMEC created the Roger Van Overstraeten Society, a foundation dedicated to the stimulation of technology for young people and bringing technological literacy to all. Their programs range from teacher training and intro classes at elementary schools to mentoring small business projects for 18-year old students to increase their high-tech entrepreneurship.

Website

- http://www2.imec.be/

Intel Lablets

Overview/goals

In 2001, Intel launched a partnership with several universities under a new model labeled “Open Collaborative Research.” This research program has several components including: open and collaborative research between universities and Intel, university research grants, and collaboration with industry partners and other labs located adjacent to universities. This partnership is expected to benefit both Intel and universities by allowing cross-fertilization of real-world, applied research with exploratory, blue-sky research in these Intel ‘lablets’, which are co-located with universities.

Institutions and partners involved

- Lablets adjacent to the University of California at Berkeley and the University of Washington in Seattle were the first to open. Since then, a lablet at Carnegie Mellon University has been added. The Pittsburgh lab actively collaborates with the University of Pittsburgh Medical Center.

Duration of partnership

- Semi-permanent

Specific science or technology focus, including area on the innovation spectrum

- Each lablet focuses on exploratory research, with the aim of investigating disruptive new technologies that may lead to new products and even new business models for Intel. The overarching theme for these lablets is “Essential Computing”, i.e. computing that simplifies and enriches all aspects of work and daily life, by going far beyond the traditional analytical and clerical tasks associated with computing.

Characteristics of partners

- Lablets are home to approximately 20 Intel researchers and engineers per lablet, with additionally 20-30 student summer interns from universities. Each university lab location was selected based on their excellence in Computer Science and Information Technology research, their fit with the Essential Computing research agenda, and their willingness to experiment with an open collaborative model of joint research.
- Each of the lablets is co-directed by an Intel employee and a local university professor. The Lab Director is a rotating, full-time position served by distinguished faculty members who are selected based on their research interests and desire to translate them to technology innovation, and usually requires a short leave of absence from academic duties. The Associate Lab Director is a permanent position held by Intel employees, who can therefore draw upon internal organizational knowledge to accelerate research impact.

Distribution of activity

- Intel employees work alongside academic researchers at labs located near the universities. For example, the Intel Research lablet at Pittsburgh is located in Carnegie Mellon University’s Collaborative Innovation Center, which also houses companies like Google and Apple.

Characteristics of funding

- Budgets for the labs are determined on an annual basis in line with Intel’s annual plan processes, and can fluctuate each year based on research agenda and priorities.

Approach to technology transfer

- The heart of the program is the Open Collaborative Research (OCR) agreement, which is based on the policy of active collaboration by all parties and non-exclusive IP rights. Under the agreement, Intel researchers and academic faculty can propose and initiate joint research projects. The terms of the agreement state that much of the research should be widely shared, even though the labs are wholly owned by Intel. The OCR does set out guidelines for patents, but they are expected to be rare, as the focus of the collaboration is openness.

Intel shoulders the burden to translate the learning into a time-to-market advantage. To facilitate technology transfer from these laboratories, a bi-directional technology transfer structure has been established that can either take lab technology downstream toward product development or infuse Intel technology into the labs and their collaborating partners.

Education and training component

- The labs host seminars, and some of the Intel researchers teach courses and hold adjunct professorships.

Systems to reward involvement in partnerships

- The Directors lead the lablets for 2 to 3 years, after which they return to their home university. This not only encourages them to maintain their ties with colleagues during their time as directors, but also lets the university know that Intel is not attempting to "steal" faculty. The policy of rotating lab directors also ensures that the research agenda of the lab is refreshed periodically with the most innovative and cutting edge research, to maintain global leadership and timely competitiveness.
- Lablet employees are eligible for the same benefits as other Intel employees including tuition re-imbursement and job specific training needed for their respective research projects.

Website

- http://www.intel-research.net/

Massachusetts Institute of Technology Media Lab

Overview/goals

- The Media lab was conceived in 1980 and founded in 1985. In its first decade, it pioneered much of the technology that enabled the digital revolution. In its second decade, it focused on embedding the digital world into the physical world. Now in its third decade, the Media Lab is focusing on “human adaptability.”

Institutions and partners involved

- The Media Lab, which is within the School of Architecture and Planning at the Massachusetts Institute of Technology (MIT), has more than 60 corporate sponsors, and also receives research support from a number of public and private funding agencies, including the Alzheimer’s Association, NIH, NSF, Office of Naval Research, U.S. Army, and U.S. Department of Veterans Affairs.

Duration of partnership

- The majority of Media Lab corporate sponsors join as consortium members, which involves a minimum three-year commitment.

Specific science or technology focus, including area on the innovation spectrum

- Current research at the Media Lab is aimed at “Inventing a Better Future,” which includes work on smart prostheses, advanced sensor networks, innovative interface design and sociable robots, among other topics

Characteristics of partners

- Current Media Lab sponsors range from consumer electronics companies to furniture manufacturers, from global publishers to one of the world’s largest consumer banks. Sponsors come from throughout the Americas, Asia, and Europe.

Distribution of activity

- Research is performed on MIT’s campus, and housed in a building holding Media lab researchers. The Lab will expand into a new building, which will connect to the current facility, early in 2010.
- Corporate sponsors who join at the consortium membership level or higher may place an employee-in-residence at the Lab. In addition, Lab researchers often travel to sponsor companies for collaboration.

Characteristics of funding

- The Lab’s annual budget is approximately $30 million, with a majority of the funding coming from its corporate sponsors.

Approach to technology transfer

- Sponsors at the consortium level or higher have access to full IP rights, license-fee-free and royalty-free, to the work done during their period of sponsorship. Non-sponsors are precluded from making use of the Lab’s developments for at least two years after the filing of a patent or copyright.

Education and training component

- Unlike other laboratories at MIT, the Media Lab comprises both a degree-granting Program in Media Arts and Sciences and a research program. For 2007-08, graduate enrollment totaled 116, with 57 master’s and 59 doctorial students. An additional 15 graduate students from other MIT departments carried out their research at the Media Lab, and more than 200 undergraduates came to work at the Lab through MIT’s Undergraduate Research Opportunities Program (UROP). Media Lab awards graduate degrees: approximately 135 graduate students are currently enrolled.
- Sponsors can recruit students to work with them as interns during breaks in the academic year, or hire them

as full-time employees following graduation. Media Lab alumni currently fill significant positions at several sponsor companies and at numerous universities.

Systems to reward involvement in partnerships

- All research groups share in the non-directed research revenue that comes to the Lab through consortia funding.

Website

- http://www.media.mit.edu/

Oregon Nanoscience and Microtechnologies Institute

Overview/goals

- The mission of the Oregon Nanoscience and Microtechnologies Institute (ONAMI) is to grow Oregon's nanoscience and microtechnology innovation capacity to leverage outside investment. This is done by competing nationally for research funds via collaborations among the various academic partners and attracting private capital to Oregon's startups by a managed "gap fund."

Institutions and partners involved

- Research affiliates include Portland State University, University of Oregon, Oregon State University, and selected researchers from the Oregon Health & Science University and the Oregon Graduate Institute, Pacific Northwest National Laboratory (PNNL).
- Corporate partners include Intel, Hewlett-Packard, FEI, Invitrogen, Sharp Labs, Solarworld, Peak Sun Silicon, Bend Research, Sony, TriQuint, ESI, and many others.
- Governmental partners include the State of Oregon, DOD, DOE, NSF, DOD, NIEHS/NIH, NIST, DOC.

Duration of partnership

- Varies

Specific science or technology focus, including area on the innovation spectrum

- The four collaborative research thrusts of ONAMI are: Microtechnology-based Energy and Chemical Systems; Green Nanomaterials and Nanomanufacturing; Nanolaminates and Transparent Electronics; and Nanoscale Metrology and Nanoelectronics.
- Activities take place across the innovation spectrum, from basic research at the universities, to products/services created by the companies.

Characteristics of partners

- Corporate partners range from startups to Fortune 500 companies.

Distribution of activity

- ONAMI has developed a cooperative arrangement for several nano- and micro-technology facilities. The agreement gives all ONAMI members and other institutional researchers equal-terms access to the equipment necessary for performing nano- and micro-scale scientific research and protoyping. The facilities also serve private clients, especially small and medium-sized companies that cannot afford their own such facilities, at appropriate market rates.

Characteristics of funding

- ONAMI was established with a $21 million investment from the Oregon State legislature, and has since received an additional $16.25M in state operating funds. ONAMI leverages support from the government in the form of grants from NIST, DOE, DOD, NIH, NSF, and also leverages private sources.
- In order to support commercialization of technologies originating at ONAMI, a "gap" grants program is available for translating research into products. These grants are available to principle investigators at either the partner universities or PNNL for proof-of-concept type work, with the goal of achieving private funding within 12-18 months.

Approach to technology transfer

- IP created while a project is supported by the gap program belongs to the grantee, but "must be managed in a manner consistent with the project commercialization goals."

Education and training component

- ONAMI partners provide a wide range of K-12 education programs on nanoscience.

Systems to reward involvement in partnerships

- ONAMI offers matching funds for competitive extramural proposals, with larger amounts available in the case of multi-institution collaborations.

Website

- http://www.onami.us/

Siemens Technology To Business

Overview/goals

- Siemens Technology to Business (TTB) program uses a team of venture technologists to investigate universities, small start-up companies, and other innovation sources for new inventions of interest to Siemens.
- The stated strategy of the TTB program is to pick the right collection of partners at universities, to work with the right government agencies, to partner with the right technical suppliers in the value chain, to do the economic value-add, and to deliver that to the customers.

Institutions and partners involved

- Siemens started a TTB lab in Berkeley in 1999 and one in Shanghai in 2005. Siemens TTB has a “dynamic working relationship” with the University of California at Berkeley. Siemens TTB looks to universities across the country for technologies to be incubated.

Duration of partnership

- Projects are selected every year and are expected take about 12-18 months to move to the next stage, where they are either integrated into Siemens or to form a company outside of Siemens.

Specific science or technology focus, including area on the innovation spectrum

- The TTB program looks for technologies that fit into Siemens’ businesses.
- TTB focuses on the core business areas of Industrial Automation and Drives, Energy Generation, Transmission and Distribution, and Clean Tech.

Characteristics of partners

- Siemens employees look to universities and nascent start-ups to identify projects to fund.

Distribution of activity

- The funded groups have an office at the Siemens TTB lab, where they can interact with Siemens employees and other groups.

Characteristics of funding

- The program provides small groups with seed-stage financing of around $500,000 and helps with early commercialization.

Approach to technology transfer

- In return for their investment in the projects, Siemens gets a percentage of each company and access to new technologies that can aid Siemens itself.

Systems to reward involvement in partnerships

- The TTB program doesn’t avert the small companies from seeking outside venture financing and selling to other customers.
- Since 1999, seven of the TTB projects have been turned into Siemens products. Additionally, 8 start-ups co-founded or seed-funded by Siemens were successful in receiving further external funding.

Website

- http://www.ttb.siemens.com/

Synthetic Biology Engineering Research Center

Overview/goals

- The Synthetic Biology Engineering Research Center (SynBERC) is a multi-institution research endeavor to set the basis for the rising field of synthetic biology.

Institutions and partners involved

- The University of California at Berkeley (UCB) took the lead in establishing SynBERC.
- Other university partners include the Massachusetts Institute of Technology, University of California at San Francisco Harvard, and Prairie View A&M University (as an outreach affiliate).

Duration of partnership

- Established in 2006

Specific science or technology focus, including area on the innovation spectrum

- Synthetic biology; research is organized around four “thrusts”: parts, devices, chassis, and human practices.

Distribution of activity

- Research is performed at university locations, by academic researchers. Corporate sponsors may attend meetings of research teams. Internships may be performed at corporate labs. Common laboratory and administrative space of approximately 36,000 square feet houses the majority of the faculty, graduate students, and post-doctoral fellows employed by SynBERC at UCB.

Characteristics of funding

- The major source of funding for SynBERC comes from NSF, providing 89 percent of SynBERCs funding in FY 2007.
- The university partners provided 9 percent of total funding in FY 2007.
- In FY 2007, industry support, through membership fees, comprised 2 percent of SynBERC’s funding.

Approach to technology transfer

- Technology transfer is stated as a major focus of SynBERC. SynBERC has a unique Venture Capital Advisory Board to help provide venture capitalists with critical information that will allow them to fund new companies in the area of synthetic biology, potentially around technology developed in SynBERC.

Education and training component

- Industry members may also have the opportunity to take on student interns.
- Students performing SynBERC research may participate in activities at many partner institutions.
- SynBERC’s flagship education program is iGEM (the International Genetically Engineered Machines competition), which helps teams of undergraduate students from around the world to develop synthetic biology projects over the course of a summer.

Systems to reward involvement in partnerships

- Industry partners can also jointly submit proposals to Federal programs that encourage university-corporate partnerships

Website

- http://www.synberc.org/

Semiconductor Research Corporation

Overview/goals

- Founded in 1982, the Semiconductor Research Corporation (SRC) is an industry consortium that manages university research on behalf of and with input from its members, who receive access to early research results and relevantly educated technical talent.

Institutions and partners involved

- Corporate members include Advanced Materials, Advanced Micro Devices, Freescale Semiconductors, Hewlett Packard, IBM, Intel, Mentor Graphics, Micron, Novellus Systems, and Texas Instruments; More than 230 universities worldwide; Federal agencies, including DARPA, NIST, and NSF; State and local governments, including California, Texas, Indiana, New York and the City of South Bend, Indiana; Strategic partners are the Semiconductor Industry Association, SEMI, and SEMATECH.

Duration of partnership

- Semi-permanent

Specific science or technology focus, including area on the innovation spectrum

- SRC supports university research related to aspects of semiconductor technology that are of interest to SRC industry members and government partners. The research is pre-competitive and results are shared among the members.
- SRC conducts three research programs that have a range of time horizons:
    - The Global Research Collaboration (GRC) fosters direct member involvement at many levels and targets research on traditional silicon-based semiconductor technologies that address industry-identified technical challenges to progress in the ~7-14 year timeframe.
    - The Focus Center Research Program (FCRP) is primarily university-directed and is focused on achieving the ultimate scaling limits of silicon-based semiconductor technologies (~14-20 year timeframe for implementation)
    - The Nanoelectronics Research Initiative (NRI) is a discovery-oriented research program with the goal of identifying new information technologies that can sustain historical exponential growth in performance and cost reductions "beyond Moore's Law." (potentially >20 years to implementation)

Distribution of activity

- Research is performed at universities around the world, but predominantly in the United States.

Characteristics of funding

- In over 25 years of operation, SRC has invested more than $1.2 billion of program funding, comprising approximately two-thirds from industry and one-third from government.

Approach to technology transfer

- SRC members receive a non-exclusive license to any IP resulting from SRC-funded research. The universities, however, own the IP and are free to license it further.
- Research results and other information are made available to participants via a dynamic web-based system.
- Periodic reviews, workshops, etc. that are for program participants only, facilitate industry awareness of research progress and opportunities for technology transfer.

Education and training component

- SRC supports over 1500 advanced degree students each year as research assistants under SRC contracts or on fellowships and scholarships that fund students directly.
- Since 1982, over 60 percent of SRC-supported students have joined sponsoring organizations or universities, or obtained a higher degree; most of the remaining graduates take positions at other high tech companies.
- SRC holds student-industry networking events and provides online resources to link job seekers and SRC member companies.

Systems to reward involvement in partnerships

- Involvement of industry technical experts in guidance and review of programs provides university faculty a much better understanding of the application of their research and of industry needs.
- Students get a three-pronged education experience. In addition to traditional coursework, each student is involved in research that is highly relevant to industry, and has an industry mentor and opportunities to experience the “real world” engineering workplace.

Website

- http://www.src.org/

University of Pennsylvania School of Medicine's Office of Corporate Alliances

Overview/goals

- The University of Pennsylvania School of Medicine forms strategic alliances/partnerships with industry via its Office of Corporate Alliances (OCA). The overall goals of alliance partnerships are to advance biomedical research, in either the academic or industry sector, as rapidly as possible to new drug/device development and then to apply these discoveries in the clinical setting for the improvement of patient care.
- The roles of the OCA include: liaison with the business community; facilitator of commercial success; assessing the blend of industry needs to the knowledge/expertise "fit" at the School of Medicine; manager of the business development process within the School and University, providing a single portal of contact for industry on all business transactions; proactive identification of any/all potential conflicts of interest; host of events to bring together the School of Medicine faculty and alliance partners that fosters an increased depth of the relationship across both organizations.

Institutions and partners involved

- University of Pennsylvania's School of Medicine and several pharmaceutical, biotechnology, and medical device companies, including GlaxoSmithKline, AstraZeneca, Pfizer, Abbott, and Laerdahl, among others.

Duration of partnership

- Partnership alliances range from 3-5 years per contract with extensions on renegotiation. The longest currently alliance is 5 years.

Specific science or technology focus, including area on the innovation spectrum

- Industry partner and faculty member agree on a set area of research focus. Because of the breadth of expertise at the School of Medicine, the approach is to first recognize the industry need and then determine if there is a specific "best fit" to address this within Penn Medicine.
- The focus with pharmaceutical partners is typically either biological discipline or disease based. The focus with the biotechnology and device sector may be either disease or technology based.
- Support is provided for all forms of business interactions, including basic science, translational research or clinical trials. Similarly the processes and outcomes span sponsored research, collaborative research, and joint development of new businesses

Distribution of activity

- Each research team is composed of both industry and academic counterparts who jointly plan the project design and conduct.
- An academic and industry project leader must jointly supervise each project. In most instances, new technology that is brought to industry from the academic partner mandates that the bulk of research activity be conducted in Penn Medicine facilities. However, aspects of many projects are paired with components that are more optimally, or more efficiently, conducted within facilities of the industry sponsor.

Characteristics of funding

- Funding decisions, and central oversight and coordination among the projects is maintained through a leadership Coordination Committee (CC), a committee that has equal representation and voting rights from each academic and industry partner.
- The total and yearly funding is negotiated in the prime contract (3-5 year duration) and is not altered thereafter. Project teams compete for funding from this central pool on an annual basis, i.e., specific project funding is guaranteed for 1 year only. Decisions on the annual fund allocation to each project are made by the CC.

Approach to technology transfer

- The general terms of IP, confidentiality, all the rights, are all pre-negotiated.
- For basic science, the IP is usually then shared, based on a weighting system of contributions. If research is conducted on a product that the company has in early clinical development, the IP belongs to the company. Any disagreements are resolved by arbitration through a mutually acceptable third party.
- With regards to joint academic-industry publications, while industry has the right to review manuscripts before submission, they cannot insist on alterations or delays to publications unless these are based on scientific fact.

Education and training component

- Results from the alliance are communicated to both the academic and industry community via a joint symposium held every two years.

Systems to reward involvement in partnerships

- Partnerships provide access to high throughput or other equipment/labor intense scientific approaches, and/or unique libraries of compounds that may not be fully developed in the academic sector.

Website

- http://www.med.upenn.edu/corporate/

Bill and Melinda Gates Foundation

Overview/goals

- The Bill & Melinda Gates Foundation is guided by the belief that that all lives, no matter where they are lived, have equal value.
- In developing countries, the Gates Foundation focuses on improving people's health and helping them lift themselves out of hunger and extreme poverty.
- In the United States, the Gates Foundation seeks to ensure that all people—especially those with the fewest resources—have access to the opportunities they need to succeed in school and life.

Year of establishment

- The Bill & Melinda Gates Foundation was created in 2000 through the merger of the William H. Gates Foundation, established in 1994, and the Gates Learning Foundation, established in 1997.

Specific science or technology focus, including area on the innovation spectrum

- The foundation's Global Health Program focuses on: accelerating access to health interventions and technologies; supporting research related to global health issues such as infectious diseases, reproductive health, and nutrition.
- The foundation's Global Development Program focuses on: funding efforts to help farmer households to improve agricultural development; funding efforts to expand access to basic financial services; and funding countries to help public libraries provide free access to computers and the internet.

Funding methods

- The foundation awards the majority of its grants to U.S. 501 (c)(3) organizations and other tax-exempt organizations. It does not award grants to individuals.

Characteristics of funding

- As of July 1, 2008, the Bill & Melinda Gates Foundation Asset Trust had an endowment of approximately $35.9 billion.
- Beginning in 2009, and continuing through the next decade, the foundation's annual payout target will be approximately $4 billion per year.

Education and training component

- The foundation's U.S. Program seeks to help those with great need gain access to the skills, tools, and knowledge needed to participate more fully in life.
- Through its education initiative, the foundation is focused on helping ensure that all students—regardless of race or family income—graduate from high school prepared to succeed in college, career, and life.
- The foundation funds scholarship programs serving a wide range of fields and educational levels, including the Gates Millennium Scholars, D.C. Achievers Scholars, Duke University Scholars, Gates Cambridge Scholars, William H. Foege Fellowships, Washington State Achievers Scholars, and others.

Specific support of public-private partnerships

- Many of the foundation's major grantees are public-private partnerships that work to develop and deliver effective solutions to global health challenges, improve agricultural production in developing nations, and expand access to college. Examples of Gates-supported public-private partnerships include: the GAVI Alliance; Medicines for Malaria Venture; the Aeras Global TB Vaccine Foundation; Ohio STEM Learning Network; and Technoserve, Inc.

  - GAVI Alliance (formerly the Global Alliance for Vaccines and Immunization) - a public-private partnership with a single, shared focus: to improve child health in the poorest countries by extending the reach and quality of immunization coverage within strengthened health services.
  - Medicines for Malaria Venture - Cre partnerships.

Website

- http://www.gatesfoundation.org/

Kaufmann Foundation

Overview/goals

- Kauffman Foundation aims to foster a society of economically independent individuals who are engaged citizens, contributing to the improvement of their communities.
- The foundation focuses its grant making and operations on two areas: advancing entrepreneurship and improving the education of children and youth.

Year of establishment

- The foundation was established in the mid 1960s.

Specific science or technology focus, including area on the innovation spectrum

- Grants go to a grantee or partner organization to fund a particular project or program related to one of their focus areas: Education or Entrepreneurship.
- The foundation works with several university partners to help them accelerate the mobilization of innovation to marketplace.
- Science and technology areas of interest include translational medicine, clean technology and biomedical engineering.

Funding methods

- The Kaufmann Foundation funds projects through grants.

Characteristics of funding

- The Kaufmann Foundation has an asset base of approximately $2.5 billion.

Education and training component

- Funds initiatives that teach and support entrepreneurship on and off college campuses.
- Supports quality entrepreneurship studies to build a body of academic research in the field.
- Funds initiatives designed to improve science, technology, engineering and math education.

Specific support of public-private partnerships

- The foundation encourages grantees to raise funds from other sources to leverage their resources.
- The foundation focuses on accelerating innovations movement from university to industry, including researching the most effective models and developing open collaborative tools such as the iBridge Network, a Web site that aggregates university inventions and discoveries.
- The foundation has helped found several public-private initiatives such as the University-Industry Demonstration Project (UIDP) and the Translational Medicine Alliance.

Website

- http://www.kauffman.org/

Kavli Foundation

Overview/goals

- The Kavli Foundation is dedicated to the goals of advancing science for the benefit of humanity and promoting increased public understanding and support for scientists and their work.
- The Kavli Foundation has established 15 research institutes at leading academic and research institutions worldwide to advance fundamental research.

Year of establishment

- The Kavli Foundation was established in 2000.

Specific science or technology focus, including area on the innovation spectrum

- The Kavli Foundation supports basic science.
- The Kavli Institutes support research in Nanoscience, Neuroscience, Astrophysics, and Theoretical Physics.

Funding Methods

- Institutes: 15 institutes in the U.S. and abroad have been established to advanced fundamental research in the areas mentioned above.
- Professorships: 6 Kavli professorships have been awarded.
- Prizes: Awarded to scientists selected by committees nominated by international academies for their groundbreaking work in the fields of nanoscience, astrophysics and neuroscience.
- Symposia: the foundation funds symposia on topics of emerging importance in Nanoscience, Neuroscience, and Astrophysics.

Characteristics of funding

- Initial funding generally is $7.5 million for each institute.
- There are three Kavli Prizes at $1 million each.

Education and training component

- The institutes and the Kavli Foundation fund research, lectures, symposia and workshops.

Specific support of public-private partnerships

- Often the Kavli institutes collaborate with centers co-located at the university.

Website

- http://www.kavlifoundation.org/

Alfred E. Mann Foundation for Biomedical Engineering

Overview/goals

- The Alfred Mann Foundation for Biomedical Engineering (AEMFBE) is a philanthropic organization that establishes university-based product development institutes known as the Alfred Mann Institutes (AMI) to expedite the delivery of compelling biomedical technology to patients more rapidly.

Year of establishment

- AEMFBE began operations in 2005.
- The first AMI was established at University of Southern California in 1998.

Specific science or technology focus, including area on the innovation spectrum

- Past and current research has focused on biomedical technologies.
- Location on the innovation spectrum is in the so-called “valley of death” between basic research and product development.

Funding methods

- AEMFBE provides an endowment to establish an institute to be housed at the selected university.
- Host universities are selected by an AMI Site Selection Committee that benchmarks and evaluates prospective universities. The selection process occurs over a 12-15 month period.
- Each AMI collaborates with the host university to identify and select up to four commercial projects initially, and then one to two per year.
- Ultimately, ten to twelve AMIs will be endowed.

Characteristics of funding

- AEMFBE was given an initial endowment of $1-2 billion.
- Each AMI is endowed with at least $100 million.

Education and training component

- Graduate students may undertake thesis research as part of a development team at a Mann Institute subject to a 90-day publication delay to secure IP rights.

Specific support of public-private partnerships

- AEMFBE focuses on bringing innovations to the marketplace; funds the research to be done by universities and then transfers the technology to companies to bring to market.
- AEMFBE supports the AMIs with market analysis and due diligence, regulatory and reimbursement guidance, cost of goods analysis and other product development activities.
- The board of directors of each AMI is composed by 50 percent of AEMFBE members and 50 percent university members.

Website

- http://www.mannfbe.org/

Appendix B: Understanding University and Industry Partners

Key Elements/Guiding Principles of University-Industry Partnerships

PCAST heard from several industry and academic leaders who have been involved in R&D partnerships. The following provides a detailed list of principles that were commonly cited as being critical in the development and maintenance of successful university-private sector research partnerships:

- ***Develop a shared vision and clear expectation for what the partnership will accomplish.*** Before entering a partnership, both parties should acknowledge each other's mission and the related objectives and constraints faced by both (these objectives and constraints are discussed below). Assessments of what each party can contribute, and the desired outcome of the partnership should be agreed upon.

- ***Address the image that some academics have of industry support as “tainted".*** Universities should acknowledge that some academics view funding from industry as having strings attached that negatively affect their research. Open and honest discussions held between parties can help address this issue.

- ***Establish porous boundaries between government, industry, and academia, by developing clusters and innovative regions.*** Developing innovative clusters and regions can reduce some of the hard barriers between partners. These clusters also can allow for a flow of inventions, ideas, and personnel between governmental, industrial, and academic institutions.

- ***Create a common organizational structure for research.*** One of the commonly cited barriers to partnerships between universities and industry is the misalignment of organizational structures. For collaborative research projects, a common organizational structure should be developed and agreed upon prior to beginning the project.

- ***Develop a strategic, long-term commitment.*** Long-term commitments are believed to deliver results that have more impact than isolated collaborative projects, and can provide a broader range of benefits to all parties involved.

- ***Enlist support from leadership and scientists.*** To fully develop successful relationships, support is required from both the researchers that will collaborate on projects and the leadership of each organization. Having a clear vision from leadership and engaging the scientists in developing and maintaining the partnership is vital for success.

- ***Focus on speed and nimbleness.*** Universities and industries typically have different time horizons regarding administrative requirements. While spending six months on reaching an agreement may be acceptable to academic partners, industry partners may be discouraged to continue as their research projects have specific timelines. Focusing on speed and nimbleness demonstrates a commitment to work with partners with more demanding time constraints, and allows for more time spent on research activities.

- ***Pre-negotiate IP and publication policies.*** Negotiations over IP are becoming more contentious and taking too much time. Of all respondents to a survey conducted by the Industrial Research Institute, 100 percent agreed that IP issues are an impediment to working with U.S. universities. Being a complex issue, there are a broad range of views on this issue and each partnership should develop its own arrangement based on the context of the collaboration. However, policies involving IP rights, publication of research results, funding of graduate students and post-doctoral fellows, and other issues should be negotiated in advance to resolve issues before they arise.

- ***Perform routine assessments.*** Scheduled reviews of research partnerships and the submission of progress reports can identify potential issues before they emerge or become insurmountable, and can allow for amendments to research priorities, as appropriate.
- ***Be transparent and consistent in action.*** It was noted that contentions over publications and IP could be avoided if both parties kept each other informed of results and their commercialization potential, both at the initiation of collaboration and throughout the partnership. Like all relationships, university-private sector partnerships are based on trust and communication, and these components are considered to be the most important preconditions for success.

Objectives, Contributions, and Constraints of Universities and the Private Sector

Public-private collaborations on R&D may take place for many reasons. The University-Industry Partnership Project, a collaborative effort between the National Council of University Research Administrators and the Industrial Research Institute, has summarized the ways that universities and industry can contribute to each other's missions, and the unique constraints that each faces[41] (Table 1). This activity later took the form of the current University Industry Demonstration Partnership (UIDP).[42] Although university-industry collaborations are just one way in which public and private actors can partner, this table exhibits the opportunities and barriers that may exist in many different cross-sectoral partnerships.

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[41] From: "Guiding Principles for University-Industry Endeavors", National Council of University Research Administrators, 2006. Available at: http://www7.nationalacademies.org/guirr/Guiding_Principles.pdf, accessed November 7, 2008.

[42] http://www.uidp.org/, accessed November 7, 2008.

Table 1: Characterizing university and industry partners' possible objectives, contributions, and constraints when entering into a public-private partnership.

	University	Industry
Objectives	• To benefit the public by adding to and sharing knowledge broadly • Educate and support an educated and well-trained workforce • Transfer technology and knowledge to enhance commercialization • Foster economic development at State and national levels	• Create and deliver new and improved products and services to enhanceprofitability • Locate advancements made by others that solve/answer general and specific problems faced by the industry partner • Develop and support an educated, well-trained, and competitive workforce
Contributions to the other partner's missions	• Training of future and current industry workforce (students) through undergraduate and advanced degrees (retention of trained work force) • Contribution to the general knowledge base for public benefit (publication) • Advancing the state of the art in a field • Acting as a filter to distill, from the general public knowledge base, a subset of that knowledge particularly applicable to industry's product needs (knowledge transfer) • Performance of specific research on behalf of industry (sponsored research) • Licensing inventions and developments (IP) for commercial purposes, including revenue generation (technology transfer) • Providing access to university-owned equipment, materials, facilities and specialized resources • Fostering economic development that expands markets • Objectively testing, evaluating and reporting on new technology.	• Employing students and graduates • Donating (equipment and money – either unrestricted or earmarked e.g., for scholarships, research, or facilities) • Providing either materials or funding for student internships and faculty sabbaticals • Employee time and knowledge donation through involvement in activities such as assisting student projects, guest lectures, service on thesis committees, service on advisory boards. • Enabling access to industry-owned equipment, materials, facilities and specialized resources • Providing leading-edge research directions • Providing financial and/or in-kind support for specific research activities of interest to the industry partner (sponsored research) • Paying technology licensing fees and royalties, which support ongoing research and educational programs • Contributing to general knowledge base (publication) • Bringing university contributions to the public in the form of goods and services (technology transfer)

Constraints	• Must educate students • Must perform research for public benefit • Must operate within changing Federal and State rules and regulations, e.g. non-profit tax rules, export regulations and increased regulations on the use of humans, animals and hazardous materials • Must manage potential and actual conflicts of interest and commitments • Must be consistent with all sponsors • Academic year limitations on student and faculty time • Facing Federal funding that is limited or nonexistent • Lack of match between industry segmentation of research and university segmentation (shared constraint)	• Research investments must show returns • Can distinguish basic and applied research, but distinction not always recognized by universities • Differences between external and internal research must be recognized and planned for by industry • External research must be part of a competitive business plan and budget • Must establish agreements in a commercially timely manner • Must establish agreements to ensure the ability to commercialize with appropriate returns • Research funded by industry usually requires clear goals, milestones, and specific time frames for completion

Acronyms

ACI	American Competitiveness Initiative
AUTM	Association of University Technology Managers
BHEF	Business Higher Education Forum
COMPETES Act	The America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act
DoE	Department of Energy
DARPA	Defense Advanced Research Projects Agency
EU	European Union
FDP	Federal Demonstration Partnership
GDP	Gross Domestic Product
GUIRR	Government-University-Industry Research Roundtable
IP	Intellectual Property
IRS	Internal Revenue Service
MNC	Multi-national Corporations
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
NSTC	National Science and Technology Council
OECD	Organisation for Economic Co-operation and Development
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
PPP	Public Private Partnerships
PCAST	President’s Council of Advisors on Science and Technology
PSM	Professional Science Masters
R&D	Research and Development
S&E	Science and Engineering
STEM	Science, Technology, Engineering, and Mathematics
UIDP	University Industry Demonstration Partnership
USD	Unites States Dollars

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