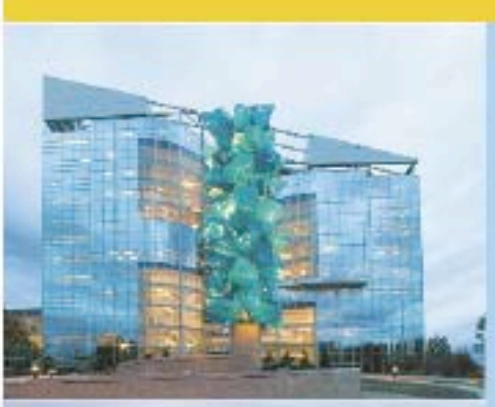

innovation associates

Technology Transfer and Commercialization Partnerships

EXECUTIVE SUMMARY

TECHNOLOGY TRANSFER AND COMMERCIALIZATION PARTNERSHIPS

Executive Summary

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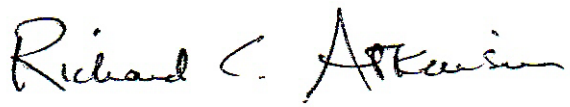
FOREWORD

Although the idea that knowledge plays a dynamic role in the wealth of nations goes back at least several centuries, recent decades have brought an unprecedented array of opportunities for industry-university collaboration. The best-known exemplars of this collaboration—MIT and Route 28, and Stanford University and Silicon Valley—make clear the enormous potential for stimulating economic growth through the dissemination of scientific knowledge. It is not only the nation's top research universities, however, that have a responsibility to advance economic growth. Other kinds of institutions, from rural universities to community colleges, have their own special and productive contributions to make. This report is a call to recognize the tremendous value of these institutions and to help them become full partners in the application of knowledge for the public good.

Like Innovation Associates' previous reports, *Accelerating Economic Development through University Technology Transfer* and *Developing High-Tech Communities: San Diego*, this study emphasizes the importance of academic partnerships with corporations, federal and state governments, foundations, venture capitalists, and entrepreneurs as contributors, collaborators, and recipients of scientific discoveries. But while partnerships are indispensable, they cannot, by themselves, guarantee success. As these studies also point out, institutions and geographic regions vary greatly in their capacity to carry out technology transfer and commercialization. Wide disparities exist in the availability of resources for translating research results into new products and processes, sufficient seed money and early-stage capital, and the entrepreneurial and management skill to transform a promising startup into a successful business. Repairing the gaps in the commercialization process is a task that urgently needs more state and federal attention. The findings and recommendations of this report are an excellent place to begin.

During my tenure as director in the late 1970s, the National Science Foundation initiated the Industry/University Cooperative Research Program, a venture that was controversial at the time but now is standard practice. We sponsored a number of early analyses of the ways in which research and development spur the economy. And NSF conducted a series of policy studies that laid the groundwork for the 1980 Bayh-Dole Act, which encouraged technology transfer by assigning patent rights to universities. We know much more today than we did then about the problems and the opportunities of innovation. I am confident that NSF will lead the way in encouraging new initiatives to build on what we have learned and to involve academic institutions of all kinds in the enterprise of economic growth.



Richard C. Atkinson
President Emeritus, University of California

EXECUTIVE SUMMARY

Technology transfer and commercialization activities in universities are skyrocketing. In 10 years, academic institutions have nearly doubled the number of licenses executed and more than doubled the number of startups launched.[1] Academic-based innovations have spurred new business development, diversified and advanced existing businesses, and contributed to job growth and economic vitality. Commercialized innovations have contributed to the eradication of diseases, advanced information technology, and brought new products and processes to market in other areas that have contributed to the health and well being of citizens everywhere. Technology transfer and commercialization by their nature are partnership driven – they involve the university linking its research upstream in the innovation chain with corporations that license the university's innovations and/or by launching startups based on those innovations. Today, there are about 200 U.S. universities and colleges that conduct some level of technology transfer.[2]

The Massachusetts Institute of Technology, Stanford University and other well-known institutions are technology transfer powerhouses, each producing about 200 licenses and about 20 new businesses every year based on university innovations. But other academic institutions are engaged in the development and transfer of innovations as well as contribute to the economic development of their regions and beyond. Despite geographic challenges and relatively modest research expenditures, universities such as Iowa State University, Brigham Young University, University of North Carolina at Charlotte and University of Akron have succeeded in licensing innovations and forming startups. In 2005, Iowa State University executed more licenses than any U.S. university except one, ranking well above universities that had research expenditures many times higher. In addition, the University of North Carolina at Charlotte and Brigham Young University, with annual research expenditures of only about $25 million have launched between two and five startups annually.

Supported by a grant from the National Science Foundation's Partnerships for Innovation (PFI) program, Innovation Associates (IA), with assistance from a National Advisory Committee, identified and examined academic exemplars. The Committee was composed of 16 national leaders in innovation, technology transfer, academia, and economic development. The exemplars selected successfully advanced innovation partnerships through technology transfer despite their modest research expenditures, rural locations and other challenges. The university exemplars were selected from institutions that ranked below the top 50 in research and development (R&D) expenditures by NSF,[3] were recommended by Advisory Committee members, and met other criteria that included (but were not limited to) a top 10 ranking nationally, relative to research expenditures, in at least one technology transfer category such as

[1] Calculated by Innovation Associates; data derived from FY 1996 AUTM Licensing Survey™ and FY 2005 AUTM Licensing Survey.™ The FY 1996 data represents 131 universities; FY 2005 data represents 158 universities.
[2] Estimated by the Association of University Technology Managers.®
[3]Source: Table 26. R&D expenditures at universities and colleges, by FY 2003 R&D expenditures: FY 1996–2003. NSF. (Latest available at the time of exemplar selection.)

patents filed, licenses executed, active licenses, and startups launched.[4] We selected a variety of examples that ranged from a major research university located in a rural area to a very small institution that specialized in a niche innovation field. IA/National Advisory Committee also selected one minority institution and one community college that exhibited exemplary innovation partnership qualities. The exemplars were Alfred University; Brigham Young University; Florida Agricultural and Mechanical University; Iowa State University; Montana State University; Rensselaer Polytechnic Institute; Springfield Technical Community College; University of Akron; University of Central Florida; and University of North Carolina at Charlotte.

This report is the first to provide a detailed description of academic institutions that are emerging; these institutions have been successful in technology transfer and commercialization even though they lack the substantial R&D funding and other factors normally associated with high-performing institutions. The research builds on previous findings on technology transfer in major research universities described by Innovation Associates in *Accelerating Economic Development through University Technology Transfer*.[5]

LESSONS AND RECOMMENDATIONS

IA found that successful technology transfer was not dependent on any one factor but instead on the confluence of multiple factors inside and outside the academic institution. Technology transfer and commercialization are as much an art as a science, and personal relations between technology transfer agents and faculty, corporate licensees, and business and investment communities were key to successful efforts. In most exemplars, the university president showed leadership and commitment to technology transfer, and it was actively embraced by deans and department chairs. These academic leaders set the tone and instituted incentives to create an academic culture that rewarded technology transfer and entrepreneurship. Their commitment often stemmed from the institution's broader mission to disseminate knowledge and innovation, and sometimes was part of the institution's engagement in economic development.

Exemplars demonstrated an understanding that excellent technology transfer is built on excellent research. Several exemplars identified their institution's core research strengths and developed strategies to build on those research strengths. Some academic institutions such as Alfred University and the University of Akron focused on specific research niches, hired known faculty in these areas, and worked in partnership with local industries to attract research funding. Several of the exemplars aggressively sought and received federal funding, which was critical to building their core research areas. Institutions such as Alfred University and Rensselaer

[4] Based on FY 2003 AUTM Licensing Survey.™ (Latest available at the time of exemplar selection.) Rank was derived by IA based on AUTM data (such as number of patent applications) per $ thousand R&D expenditures.
[5] Diane Palmintera, *Accelerating Economic Development through University Technology Transfer*, Innovation Associates, 2005. (To download go to www.InnovationAssociates.us)

Polytechnic Institute also benefited from state funds that supported collaborative research centers, and used these state monies to leverage federal funds.[6]

Many of the successful academic institutions had a history of working with corporations in their community and state. For example, Iowa State University had long-established relationships with the agricultural sector, and the University of Akron had a history of success in working with chemical and polymer industries. The Universities' service to those industries through various outreach, extension services and research partnerships developed personal, trusted relationships that paid off later in successful technology transfer outcomes. Moreover, these institutions emulated other successful research universities by focusing more on building strong corporate and entrepreneurial relationships and less on immediate technology transfer outcomes. The institutions' leaders recognized that the benefits of entrepreneur, corporate and foundation contributions and sponsored research were often far greater than the potential royalty income earned from technology licenses. As a result, several of these institutions such as Rensselaer Polytechnic Institute have received substantial financial donations from successful entrepreneurs and others associated with the institution.

An important element in launching startups based on academic research was the presence of entrepreneurial resources, including seed capital and incubation, and the linkages between technology transfer activities and these resources. This was especially true for institutions located in rural and other areas with few entrepreneurs and little investment capital. Rensselaer Polytechnic Institute, for example, developed one of the nation's earliest incubators and research parks in order to fill a gap that existed in the traditional industrial community in which the Institute was located; Iowa State University also created incubation space and a research park to help retain spin-offs in the University's rural community. In most cases, state and community support were essential in establishing and maintaining entrepreneurial infrastructure and services at or around academic institutions.

The findings from case studies on exemplars form the basis for recommendations provided here. In addition, many members of the National Advisory Committee provided input to the recommendations, particularly the recommendations directed to national policy makers. We provide recommendations for three groups: (a) academic leaders, and (b) state and local leaders, and (c) U.S. national policy makers.

[6] Reference is to state Centers for Advanced Technology funded by the New York Office of Science, Technology and Academic Research.

RECOMMENDATIONS FOR ACADEMIC LEADERS

Building the Innovation Pipeline

- **Focus on building excellent research and leveraging research strengths.** Excellent technology transfer is based on excellent research. An institution that wants to build its technology transfer capacity should start by assessing its core research competencies and developing strategic plans to enhance those competencies.

- **Target and build niche research strengths.** Academic institutions with limited research funding have been successful in creating technology partnerships and conducting technology transfer by identifying and focusing on specific research niches. Examples include University of Akron that focused on polymer research and Alfred University that focused on ceramics research.

- **Aggressively pursue federal funds to support research strengths.** Federal funds generally represent more than three-fifths of research expenditures in academic institutions.[7] Increases in technology transfer outcomes often are associated with increases in research funding, and increases in research funding almost always involve greater federal awards.

- **Build research strengths in space dominated by local industries.** The University of Akron built its polymer research, in part, with partners from chemical corporations in Northeast Ohio. Alfred University also built its ceramics department and centers with the help of ceramics companies in Southwestern New York. Close industrial relationships provide a window into corporate research needs and opportunities as well as direct research support.

- **Create research centers that involve industry members.** Research centers that involve industry members provide a natural link to the industrial community. Although there is no empirical evidence that suggests these centers increase technology transfer outcomes, technology transfer occurs in many informal and indirect ways. In research centers that involve industry members, the reciprocal flow of information between industries and academic institutions happens naturally and benefits both parties.

- **Tap foundations and successful entrepreneurs to build research capacity and entrepreneurial programs.** Exemplars such as Rensselaer Polytechnic Institute, Iowa State University, Brigham Young University and others benefited substantially from corporate foundations and successful entrepreneurs funding major research centers,

[7] In FY 2005 federal funding sources represented 63.8 percent of total R&D expenditures in the top 200 academic institutions. Source: Table 31. R&D expenditures at universities and colleges, ranked by all R&D expenditures for the first 200 institutions, by source of funds: FY 2005. NSF.

schools, and centers for entrepreneurship. Academic institutions also benefited from successful entrepreneurs who contributed time and "in-kind" services.

Promoting Technology Transfer

- **Set a tone that supports a technology transfer culture.** In many academic institutions that are successful in technology transfer, the institution's president articulates support for technology transfer as an important part of the institute's mission. The president's support often is articulated in the institution's strategic plans and goals, and this sends a strong message to department heads and faculty. This is the case in many exemplars including University of Akron, University of North Carolina at Charlotte, and Rensselaer Polytechnic Institute. Institutional support also is demonstrated by the institution's hiring and faculty promotion decisions that reward work with industries and technology transfer. In addition, "buy-in" and leadership from deans and department chairs are critical to faculty participation in technology transfer and industry partnerships.

- **Raise technology transfer to a higher level and promote excellence.** Institutions that want to promote technology transfer should structure reporting relationships sufficiently high in the institution, and fund operations to reflect goals set by the institution. Hiring practices should focus on attracting top personnel with excellent technology transfer credentials, industrial/entrepreneurial background or experience working with industries and entrepreneurs, and demonstrated teamwork. Internal promotion policies should reward technology transfer excellence. At the same time, professionals should be held to performance goals, and technology transfer offices should be expected to produce significant and "real" outcomes that result in the most productive innovation transfers.

- **Focus on building industry partnerships to achieve long-term benefits rather than short-term "pay-offs."** Many universities that exhibit exemplary technology transfer outcomes work with industries in ways that may not produce direct and immediate results. For many years, universities with high-yield technology transfer outcomes have worked routinely with corporations through research and other collaborative relationships without expecting payback. In the long-run, these universities ultimately benefit from their long-term corporate relationships. The institutional benefits derived from successful entrepreneurs who fund endowments, laboratories, new/improved schools, etc. most often far exceeds that of near or future license income.

- **Build flexibility and responsiveness into technology transfer programs.** Corporate research partners and corporate licensees of university innovations increasingly complain that academic institutions are not flexible and do not sufficiently take into account their needs. Academic institutions should build robust, flexible and mutually beneficial partnerships with the private sector and state/federal agencies that build and nurture research and commercialization partnerships.

- **Make a commitment to economic development.** Some academic institutions have a tradition of service to the agricultural, industrial and business communities. The leaders

in these institutions recognize that their engagement in community and state economic development can have a major economic impact that ultimately benefits the institution. Their support for research partnerships with industry, and technology transfer and commercialization are often natural extensions of the institutions' economic development and service commitments.

- **Focus on launching startups as part of the institution's technology transfer and economic development commitments.** By launching startups, academic institutions begin to build a critical mass of science and technology enterprises that are likely to locate in the region, especially given proper infrastructure and services. As these startups grow and spin off other startups their value exponentially increases. This growth ultimately benefits academic institutions by improving the entrepreneurial and economic environments that attract top faculty and students.

Fostering Entrepreneurship to Support Commercialization

- **Build entrepreneurial resources in academic institutions and link technology transfer activities to those resources.** In order to effectively launch startups, academic institutions should have in place entrepreneurial infrastructure and services, and/or close linkages with those resources in the community and state. These entrepreneurial resources include incubators, research parks, enterprise forums, mentoring, and other business development services. Institutions with modest research funding can start by setting aside incubation space and providing some business development services.

- **Coordinate technology transfer and entrepreneurial services.** Technology transfer offices should actively identify and refer potential startups to internal and external entrepreneurial resources. Moreover, technology transfer offices, incubators, entrepreneurial development centers, etc. should regularly communicate to insure coordination and effective flow of services.

- **Increase linkages with sources of investment capital for startups.** Seed capital is an essential ingredient in launching startups. Startups associated with small academic institutions and those located in areas with few venture capitalists are particularly challenged. It is especially important for technology transfer offices in these academic institutions to identify and establish relationships with sources of seed capital, which may include angel networks, venture capital firms focused on early-stage investments, enterprise forums, and state venture capital programs.

- **Build networking opportunities.** Successful technology transfer activities almost always have internal and/or external networks available to academic-based innovators. These networking opportunities facilitate introductions between faculty innovators and potential licensees, partners, investors and service providers.

Building Credibility and Awareness

- **Capture the results from technology transfer and other industry partnerships.** One of the best ways to increase support for technology transfer inside and outside the university is to capture and publicize successes. Most academic institutions active in technology transfer collect data for the AUTM Licensing Survey,™ but some collect additional data and attempt to assess value. This provides the justification needed to support the allocation of funds within academic institutions and, in the case of public universities, funding from state legislatures.

- **Publicize technology transfer successes.** Publicizing and celebrating successful faculty innovators adds academic legitimacy to technology transfer activities and encourages future innovators. It also encourages local and state support for research, technology transfer and related entrepreneurial efforts.

- **Educate state policy makers on the value of technology transfer and industry research partnerships.** States support university technology transfer in many ways – by providing funds for university-industry research, seed/venture capital, entrepreneurial infrastructure, recruitment of academic "stars," and tax incentives to stimulate investments in university research and startups. It is critical that academic institutions that benefit from these funds and incentives regularly educate policy makers on the value to and return on the state's investments.

- **Educate federal policy makers.** At the federal level, there are many programs that directly or indirectly impact university technology transfer including basic research, industry-university collaborative programs, entrepreneurial development infrastructure and services, and small business innovation research and commercialization. Academic leaders should actively support these programs/policies that impact their ability to create, develop and transfer innovations. Moreover, academic and other leaders interested in realizing the benefits derived from technology transfer should actively initiate and support federal efforts to enhance commercialization efforts.

RECOMMENDATIONS FOR STATE AND LOCAL LEADERS

Promoting R&D Funding, Collaboration and Technology Transfer

- **Create and fund new initiatives to bridge the "valley of death."** Academic practitioners in the exemplars covered in this report and previous reports covering major research universities almost all point to gaps in early-stage capital, management capacity, and other business-related issues as stumbling blocks in the development of successful academic-based startups. Government-related entities should explore options and implement pilot projects designed to better address these gaps. These initiatives should be designed especially to stimulate and leverage private sector involvement and solutions.

- **Promote research, collaboration, technology transfer and enterprise development at the highest level.** The tone set by the state governor and state legislature can affect the economic and technology transfer direction in academic institutions, particularly state-related institutions. However, policy makers must carefully consider input from stakeholders before forming policy conclusions, and should take a long-term view regarding economic returns. In addition, policy makers should be careful to ensure that the expectations imposed upon the academic institutions are realistic.

- **Work with academic institutions to identify core competencies**. Economic development professionals can help academic institutions identify core research competencies as well as regional, industrial R&D strengths. By working with academic institutions to identify research strengths and opportunities, state/local organizations can add value to institutional strategic plans designed to build a research pipeline for future business and economic growth.

- **Provide state funding for targeted R&D in academic institutions.** A number of states provide competitive grants to academic institutions in targeted research areas, normally associated with state clusters. These grants often are used to build up research in areas that the state has a competitive advantage or to spur new R&D in emerging fields. Many universities use these state funds to leverage federal funding, and while state grants tend to be small, they can result in federal funding many times that of the state's original investment. Academic institutions in New York and Ohio, for example, have effectively used R&D grants to leverage federal funding.

- **Encourage industry-university R&D collaboration by funding cooperative grants and research centers, and implementing tax incentives.** States such as New York provide a suite of initiatives designed to encourage industry-university R&D collaboration including Centers for Advanced Technology, competitive grants that require collaboration, and other incentives. These programs and incentives promote R&D that are relevant to industries' needs and focus on commercialization as an end product.

Building an Entrepreneurial Environment

- **Develop/enhance regional infrastructure and services to capture and retain startups from academic institutions.** The entrepreneurial infrastructure, services and investment capital available to entrepreneurs, in part, will determine whether startups from academic institutions remain in the community and state or relocate elsewhere. State and local governments should evaluate whether they have sufficient entrepreneurial conditions to retain startups at various stages in the business development cycle.

- **Build investment and networking opportunities.** Communities and states, particularly those in rural areas and areas with little venture capital can enhance the potential of local/state entrepreneurs by building and supporting angel capital networks, seed capital

funds, "fund-of-funds," and enterprise forums.[8] Moreover, community/state organizations can facilitate entrepreneurial growth by providing networking opportunities that introduce entrepreneurs to potential investors, customers, partners and service providers.

- **Educate academic institutions about local/state entrepreneurial resources and coordinate the resources with those at academic institutions.** Economic development corporations, state technology programs, and others that provide entrepreneurial services should educate university technology transfer offices, entrepreneurship centers, etc. about the community/state's entrepreneurial resources. They should work with the academic institutions to coordinate services and insure academic and local/state resources leverage and add value to the other.

- **Develop programs and work with academic institutions to improve Small Business Innovation Research (SBIR) awards.** Many states have developed programs to help startups write SBIR/Small Technology Transfer Research (STTR) proposals, and Phase I awardees transition to Phase II/III through gap funding and commercialization assistance. State and local organizations that provide SBIR/STTR assistance should work with academic institutions to insure that affiliated startups are aware of and receive these services.

Promoting Academic Institutions as Economic Assets

- **Work with corporations and foundations to encourage sponsorship of and participation in academic-based R&D, technology transfer and entrepreneurship.** Business, technology and economic development organizations can act as intermediaries to help "market" academic institutions to local/state foundations, corporations, successful entrepreneurs, etc. They can work with industrial liaison and technology transfer offices to provide introductions and help liaise between corporations and the institution.

- **Market academic institutions as community/state economic assets.** State and local organizations can work with the university's press office, technology transfer office, and incubator/research park to publicize successes locally, regionally, and nationally. The organizations can sponsor media events such as local award dinners that help create an entrepreneurial atmosphere in and around the academic institution.

- **Encourage academic leadership to become fully engaged in economic development.** State and local organizations can organize meetings between the university leadership, policy makers, corporations and other key stakeholders and otherwise facilitate university engagement in economic development and alignment of strategies and goals.

[8]For more on various types of seed funding go to www.cfi-institute.org, www.ncet2.org, www.nasvf.org, and www.nvca.org.

- **Help academic institutions evaluate their impact on local and state economies and present the outcomes to policy makers.** Academic institutions, particularly state universities, need credible economic impact data to justify their requests for state funding of research, technology transfer and entrepreneurial activities. Helping the university "make its case" serves the institutions' and the community/state's economic interests.

RECOMMENDATIONS FOR U.S. NATIONAL POLICY MAKERS

- **Recognize that innovation involves advancing science and technology at various levels, by multiple means and through a wide range of academic institutions.** Various types of academic institutions provide different but nevertheless important elements in advancing and disseminating innovations. These institutions range from major research universities that develop next-generation innovations to colleges that produce "low-tech" but valuable applications to community colleges that educate a technical workforce and increasingly entrepreneurs. Federal policies and funding should focus on stimulating innovation, collaboration, technology transfer in the broadest sense, and entrepreneurship through various means and in a wide range of institutions. Moreover, policies and funding should encourage comprehensive strategic planning, and greater coordination and cooperation between these institutions.

- **Create and fund new initiatives to bridge the "valley of death."** Academic practitioners in the exemplars covered in this report and previous reports covering major research universities almost all point to gaps in early-stage capital, management capacity, and other business-related issues as stumbling blocks in the development of successful academic-based startups. NSF and/or other government-related entities should explore options and implement pilot projects designed to better address these gaps. These initiatives should be designed especially to stimulate and leverage private sector involvement and solutions.

- **Promote regional R&D partnerships.** As NSF has promoted industry-university R&D partnerships, it also should more strenuously promote R&D partnerships that cross county and state boundaries. Several exemplars in this report participated in federally-supported, regional partnerships that brought together the best academic and industrial minds in a field such as nanotechnology. The nation faces global competition that requires partnerships among the best institutions in emerging scientific and technological fields. Federal funding should stimulate and support regional partnerships wherever possible.

- **Provide additional funding for partnership-related activities.** Although PFI is a small program, it has had a positive impact. It is one of the few federal programs that facilitate flexibility and experimentation involving partnerships to promote innovation. The PFI program should be expanded and should coordinate with other NSF and federal programs to leverage these programs, where possible. In addition, the PFI program could be replicated or adapted by other federal agencies that fund major research in life sciences,

energy, defense and other areas. Other NSF programs that promote partnerships such as I/UCRCs also should be expanded.

- **Assess and address the effect of technology transfer from a corporate perspective.** Research directors at academic institutions covered in this report and previous reports on major research universities were quite concerned about the potential negative impact of current technology transfer practices on industrial research partnerships. NSF or other appropriate entity should undertake an evaluation and organize discussions with the private sector to develop policies that optimize industry-university R&D relationships as well as protect university intellectual property rights.

- **Develop metrics that effectively capture the value of innovation-related activities.** The NSF or other appropriate entity should organize an effort to develop metrics that will reflect the true value of technology transfer and commercialization activities. The metrics should include long-term outcomes such as the retention and growth of startups as well as other measures. In addition, the NSF should work with leading organizations and institutions to improve data collection procedures and reporting, and to insure not only the accuracy but also the usefulness of the data.

- **Create a clearinghouse for technology transfer data and best practices.** The NSF or other appropriate entity should create a clearinghouse to provide on-going data collection and best practices that are readily available to the community. Such a clearinghouse should be actively involved in the dissemination of those data and best practices to universities, industries, state governments and national trade organizations. Professional organizations and representative institutions should be involved in any such effort.

- **Review government-wide incentives and support for small technology enterprises.** Many of the exemplars for this report and previous reports used federal and state programs and services to increase SBIR/STTR participation and to help startups develop business and marketing plans, increase management capacity, locate investment capital, and meet other critical needs. While some of these programs are useful, others are outmoded and limited in their ability to address the needs of entrepreneurs and technology startups. NSF or other appropriate entity should identify and assess various federal incentives and programs that are intended to stimulate and assist small technology enterprises, and provide recommendations for improvements.

- **Provide technology transfer and commercialization education and mentoring activities in emerging academic institutions.** Academic institutions in EPSCoR and other states, and minority institutions would benefit from NSF initiatives to educate and help them organize technology transfer activities. Moreover, a mentoring program that would team a successful university with an emerging institution would be one effective way to address weaknesses in emerging institutions.

Although these recommendations cut across different types of academic institutions, some recommendations are more important for those institutions challenged because of location, modest research funding and other factors that make it more difficult for them to transfer technologies. For example, it is especially important for modestly funded institutions to focus on building niche research areas. In addition, academic institutions located in rural or traditional industry areas often have fewer entrepreneurial and investment resources available to them, and therefore have a greater need to develop internal resources and pro-actively seek linkages with external resources. These resources usually involve state and federal government support for entrepreneurial infrastructure and services, and incentives to stimulate and attract early-stage capital. Moreover, emerging institutions often must provide more aggressive technology transfer and entrepreneurial incentives to build an innovation and entrepreneurial environment.

OUTSTANDING ISSUES

Technology transfer and commercialization are part of an innovation continuum that starts with basic research and ends with the introduction of a product, process or service in the marketplace. It exists as part of a larger, dynamic "ecosystem" that involves many factors including culture, environment, and processes that affect its optimization. In that context, we briefly discuss three outstanding issues that affect the ability of academic institutions to achieve successful technology transfer and commercialization.

Commercialization and the "Valley-of-Death"

The most pervasive issue that impedes commercialization of academic-based innovations commonly is referred to as the "valley-of-death."[9] There are many factors that contribute to the valley and these factors differ somewhat depending upon whether an academic institution transfers an innovation by licensing it to an established corporation or by launching a startup. If an innovation is launched through a startup, investment capital particularly seed and early-stage capital is often a key factor in the ability of the startup to commercialize the university-based innovation. Other factors involve building sufficient business and management capacity. If institutions that launch startups are located in areas with few entrepreneurs and venture capitalists, these obstacles to commercialization become even greater. Whether a university-based innovation is licensed to an existing corporation or transferred by launching a startup, major commercialization impediments also often revolve around the innovation's early developmental stage and lack of direct and immediate applicability for commercial use.

The federal government spends about $141 billion per year in R&D and invests almost $30 billion of that amount in academic R&D.[10] But it devotes an insignificant amount to the

[9] For our purposes here, we describe the valley of death as the gap between later stage, academic-based innovations and the commercial application of those innovations in the market place.

[10] $141 billion is a FY 2007 estimate by the American Association for the Advancement of Science (AAAS) based on final FY 2007 appropriations (P.L. 110-5); Table I-4. Major Functional Categories of R&D, AAAS R&D FY 2008. AAAS. Source for federal government funding of academic R&D: Table 31. R&D expenditures at

technology transfer and commercialization of the research, and the partnerships that facilitate it. The "commercialization side" of research has been the missing link in the pipeline that moves innovation from research to the marketplace. NSF and national policy makers should not only be concerned about expanding the research pipeline but also accelerating the research through it. In response, we have recommended that national policy makers address the "commercialization side" of technology transfer by exploring options to bridge the valley-of-death and implement pilot projects to test promising options.

Involvement of Minority Institutions and Colleges

Discussions on innovation, technology transfer and commercialization rarely involve minority institutions, non-research intensive institutions, and community colleges. These institutions have a role in innovation, and greater partnerships between research universities and colleges are called for to address the full spectrum of innovation and innovation dissemination. In addition, minority institutions often are challenged in technology transfer and entrepreneurial development because of limited funding, a lack of attention by top administrators, and limited experience. In order to address some of these weaknesses, we have recommended that academic institutions successful in technology transfer educate and mentor minority and other emerging institutions.

Technology Transfer Effects on Industry-University Relations

An increasingly common concern being voiced by university research directors is that corporations are more hesitant to engage in research partnerships because of more stringent university protection of their intellectual property. Although we do not have empirical evidence to support their contentions, some research directors believe that increasing pressure to formalize technology transfer agreements early in the research process has led to decreasing sponsored research. In response to these concerns, we have recommended that NSF or other appropriate entity more thoroughly assess the effect of technology transfer practices from a corporate as well as academic perspective, with the intent of developing practices that optimize industry-university R&D relations as well as protecting the university's intellectual property rights.

CONCLUSIONS

In conclusion, the nation is experiencing rapidly expanding academic-based, technology transfer and commercialization. This growth has been fueled by expanding federal research funding, facilitated by relationships between academic institutions and corporations, and promoted by academic leadership. The benefits derived from technology transfer include greater academic attraction of top, entrepreneurial-minded faculty and students, return on investments from successful entrepreneurs and corporations that "give back" to the institution, long-term improvement of the institution's entrepreneurial and economic environment, and fulfillment of the institution's mission to disseminate knowledge and innovation.

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universities and colleges, ranked by all R&D expenditures for the first 200 institutions, by source of funds: FY 2005. NSF.

Academic institutions that have modest research funding face different challenges than those with greater funding. We have addressed some of the ways in which universities with modest research expenditures can achieve technology transfer results; that is, by (a) promoting a technology transfer and entrepreneurial culture, (b) identifying and focusing on research niches, (c) working with states and local industries to leverage industry-university strengths, (d) pursing federal research funding, (e) implementing hiring and promotion policies that reward technology transfer and entrepreneurship, and (f) creating and linking entrepreneurial resources to technology transfer activities in order to effectively launch startups.

An implicit, overriding theme in this report involves more broadly defining innovation and expanding the view of innovation players. Innovation is not only high-tech – it encompasses many types of R&D and related activities, at many levels and in different types of academic institutions. In addition, technology transfer has increasingly become defined as the protection of intellectual property. But more broadly defined, technology transfer involves informal as well as formal relationships, services, and exchanges that mutually benefit each party.

Academic institutions challenged because of limited research expenditures and location can be successful in technology transfer, and investors and corporate customers would do well to include a broader spectrum of institutions when seeking new innovations for licensing and development. We encourage academic leaders to engage in all aspects of technology transfer and commercialization, and policy makers to provide the support and incentives needed to bridge current gaps, thus encouraging a greater number and variety of institutions to participate and benefit.

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