Accelerating Innovation: The Nanotechnology Institute

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Abstract

Revolutionary and high impact technologies are no longer being developed by private industry in the U.S. to the extent they were forty years ago. An ever-increasing number of these advances now arise from early discoveries supported through federal funding. Universities, research institutions, and federal laboratories are a critical spawning ground for these innovations. Yet the process by which they reach the marketplace, adding value to the economy through investment, company formation, and job creation, is severely and unnecessarily hampered by decades-old and obsolete policies throughout the technology development process, as well as a lack of strategic investment that could significantly boost their success. This is particularly problematic in new technology areas such as nanotechnology, where global competitiveness hinges crucially on gaining early technological footholds.

The Nanotechnology Institute™ (NTI) is a novel example of an innovation ecosystem that has succeeded in removing these barriers to enable and accelerate the commercialization of university research in nanotechnology. Created in 2000, the NTI's founders recognized that overcoming these

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barriers to innovation and entrepreneurship in the twenty-first century requires completely new thinking and new structures. The NTI addresses this challenge by uniquely combining the following key elements: (1) a core public investment of funds carefully managed by a leadership team that integrates faculty, economic development experts, and university technology transfer officials at the same administrative level; (2) multi-university participation through a novel, comprehensive IP-pooling and revenue-sharing strategy; (3) strategically-targeted grants to universities and loans to small businesses that promote faculty-industry collaboration and prioritize university IP with commercial potential; (4) strong emphasis on interdisciplinarity, regional strengths, and high quality research; (5) recruitment of commercialization experts in oversight and program review, and solicitation of university technology transfer professionals in prioritizing projects to fund; and (6) extensive outreach, networking, information sharing, and marketing efforts. These coordinated activities are generating tangible outcomes at an accelerating pace: In the past three years the number of new IP assets, technology licenses, and new company spinoffs has exceeded all activities in the previous seven years. This has led to the establishment of new organizations modeled on the NTI program. Most importantly, these activities are now being reflected in real economic impact for the region in terms of job growth. This reflects not only the maturation of nanotechnology in general, but the success of the NTI model in particular.

I. Barriers to the Commercialization of Innovative Technologies

Advancing the commercialization of innovative technologies requires the removal of barriers to the commercialization of federally funded research. These limitations are clearly delineated, for example, in the National Economic Council's September 2011 policy paper, "A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs."[1] One of the primary barriers resides between the technology transfer offices and the companies seeking to license innovative technologies. Another exists due to the lack of regional clusters, which can be described as networked geographic concentrations of companies, suppliers, support services, financiers, specialized infrastructure, and research institutions whose competitive strengths are synergistic when shared. Comprised of academic institutions, research laboratories, small and large companies, economic development organizations and capital providers, these clusters move technology forward by bridging commercialization barriers to stimulate business formation and create jobs. As further described in the charter of the Department of Commerce's new Office of Innovation and Entrepreneurship, new thinking, new policies and new foundations are required to "unleash and maximize the economic potential of new ideas by removing barriers to entrepreneurship and the development of high-growth and innovation-based businesses."[2] The growth of regional innovation clusters and proof-of-concept centers are potential solutions to overcome these barriers.

While the issues surrounding the transfer of intellectual property to the market are well recognized, it is only recently that regional clusters have been a focus of policy studies.[3] These studies

[1] *See* NAT'L ECON. COUNCIL, A STRATEGY FOR AMERICAN INNOVATION: SECURING OUR ECONOMIC GROWTH AND PROSPERITY (2011), *http://www.whitehouse.gov/innovation/strategy* (last visited Aug. 18, 2011).

[2] Press Release, U.S. Department of Commerce, Commerce Secretary Locke Announces New Commerce Initiatives to Foster Innovation and Entrepreneurship (Sept. 24, 2009).

[3] *See* JONATHAN SALLET ET AL., CTR. FOR AM. PROGRESS, THE GEOGRAPHY OF INNOVATION: THE FEDERAL GOVERNMENT AND THE GROWTH OF REGIONAL INNOVATION CLUSTERS (2009), http://www.scienceprogress.org/wp-content/uploads/2009/09/eda_paper.pdf (last visited Aug. 4, 2011); ASS'N OF UNIV. RESEARCH PARKS, THE POWER OF PLACE: A NATIONAL STRATEGY FOR BUILDING AMERICA'S COMMUNITIES OF INNOVATION (2008), http://www.aurp.net/assets/documents/pop_npc_pres.pdf (last visited Aug. 14, 2011).

have confirmed the observation that "place matters." However, few studies and even fewer existing programs address the *integration* of both these issues into one entity. Many existing programs fall short because they are not organized systemically to leverage the advantages of an innovation cluster.[4] Barriers to success also include:

- Lack of commercialization expertise at many research institutions where innovative technology is born;
- Lack of access to enough seed-stage and early-stage venture capital, including insufficient funding to support applied research aimed at enhancing the commercial potential of IP (as opposed to basic research which, by definition, avoids going that far toward application);
- Insufficient or inconsistent recognition and support at universities for research with commercial aims, including lack of close working relationships between faculty and technology transfer offices, and lack of faculty time and knowledge of the technology transfer process;
- Lack of management talent, workforce talent and industry-specific talent to create local companies;
- Lack of a systematic innovation partnership between the federal government and state and local governments;
- Lack of a "critical mass" of supportive individuals and business in these tech areas.

Each of the above barriers is exacerbated by the current economy and subsequent shifts in the technology development pathway whereby:

1. Large companies are downsizing or eliminating internal innovation programs, relying more and more on smaller companies and universities for new ideas via open innovation strategies;
2. Small companies are trapped by:
3. The need to find large companies to partner with because the small company's ability to grow is hampered by the current economic climate, combined with,
4. The lack of resources to identify opportunities either via other small companies or technologies developed at research institutions,
5. The lack of experienced entrepreneurs to lead management teams,
6. The lack of capital necessary to reach commercialization;
7. Universities and research institutions need more incentives and better ways to move their technologies to the marketplace; whether it is to a small or large company is irrelevant.

[4] *See e.g.*, THE NANOTECH. INST., COMMERCIALIZING UNIVERSITY INNOVATIONS: THE NANOTECHNOLOGY INSTITUTE SUCCESS STORY (2010) (NTI's response to an Office of Science and Technology Policy request for information), *http://www.eda.gov/PDF/143_Nano%20Tech%20Institute.pdf* (last visited Aug. 14, 2011); FRED BLOCK & MATTHEW KELLER, THE LONGVEW INSTITUTE, BUILDING ON SUCCESS: REFORMING THE US INNOVATION SYSTEM (2008), *http://www.longviewinstitute.org/stimnovation2* (last visited Aug. 14, 2011).

II. The NTI Model

The Nanotechnology Institute™ (NTI) represents a radical departure from previous models of innovation.[5] As this new model for innovation and entrepreneurship enters its tenth year, it has far exceeded the goals of its creators. The NTI seeks to break down barriers between institutions and disciplines, to focus on technology transfer and commercial outcomes, and to bring a range of talents to bear on specific technology opportunities, yielding a tangible increase in IP creation, technology transfer and commercial development. The NTI has focused its efforts on increasing the nanotechnology research enterprise, linking research institutions together, creating new intellectual property, fostering a vibrant innovation ecosystem for commercial ventures, and marketing our geographic region nationally and internationally. A key foundational accomplishment of the NTI includes the establishment of its innovative legal and programmatic structure within which regional universities collaborate at all levels to promote nanotechnology research with potential payoff in economic development (Figure 1).

1. Project Background

The Nanotechnology Institute™ (NTI) is a multi-institutional, non-profit organization whose unique mission is to accelerate nanotechnology commercialization through interdisciplinary translational research that flows from academic laboratories to industry through company formation and product development. Founded in 2000 by the University of Pennsylvania, Drexel University, and Ben Franklin Technology Partners of Southeastern Pennsylvania (BFTP/SEP), the NTI's goal is to bridge the gap between nanotechnology research and commercialization to develop the regional economy and to realize the promise of nanotechnology for societal benefit. Significant emphasis is currently devoted to addressing opportunities in the health/life sciences and alternative energy, with additional programs in a range of specifically targeted areas including materials, electronic devices, and sensors.

The NTI is the first nanotechnology commercialization partnership of its kind and serves as an innovative model due to the unprecedented level of cooperation, collaboration, and strategic coordination between its 13 academic institutions and an economic development agency in the Southeastern Pennsylvania metropolitan area (Table 1). Together, these universities comprise over 4000 research faculty and over $1 billion of annual research expenditures.

Table 1. Members of the NTI

FOUNDING MEMBERS	University of Pennsylvania
	Drexel University
	Ben Franklin Technology Partners of Southeastern PA
AFFILIATE MEMBERS	Children's Hospital of Philadelphia
	Fox Chase Cancer Center
	Harrisburg University of Science and Technology
	Lehigh University
	Millersville State University
	Philadelphia University
	Temple University
	University of the Sciences

[5] KIRSZTINA HOLLY, IMPACT: INNOVATION MODEL PROGRAM FOR ACCELERATING THE COMMERCIALIZATION OF TECHNOLOGIES (2009), *http://stevens.usc.edu/docs/IMPACT%20Initiative%20Whitepaper.pdf* (last visited Aug. 14, 2011).

	Villanova University
	Widener University

The NTI receives its core funding from the State of Pennsylvania's Department of Community and Economic Development's Ben Franklin Technology Development Authority University Research Commercialization Grant Program as part of the Pennsylvania Initiative for Nanotechnology (PIN). Recognizing that support of early-stage technology development can lead directly to economic growth, the PIN program has provided over $90M in funding to six nanotechnology centers over the past ten years and produced over $500M in leverage,[6] although the NTI is one of only two of those that focus on commercialization. The NTI is also supported by substantial matching funds from the core institutional partners. Since its creation, the NTI has grown into a mature organization centered on a common framework of technology development funding, intellectual property (IP) management, sponsored research agreements, new company formation, and revenue generation.

The NTI model incorporates commercialization objectives through the expertise of BFTP/SEP, the leading economic development agency in the Southeast Pennsylvania region. Over its 28-year history, Ben Franklin has been widely recognized and modeled by other states and countries. The Pennsylvania Economy League, a nonpartisan research organization, conducted an independent, objective evaluation of the economic impact of the partnership from 2002 through 2006. Its report documented that for every $1.00 invested in Ben Franklin, $3.50 was returned to the state treasury. Since 1989, the Ben Franklin Partnership has boosted Pennsylvania's economy by more than $17 billion dollars. In addition, the jobs created by Ben Franklin's clients paid 33% higher than the average nonfarm salary in Pennsylvania as a whole. As well, over 125,000 job-years, that is, years of full-time work, were created as a result of BFTP investments and services.[7] The network was acknowledged by the U.S. Department of Commerce in 2008 with the Technology-Led Economic Development Award, and the International Economic Development Council named the statewide Ben Franklin program as the winner of its Excellence in Technology-Based Economic Development Award.[8] The U.S. Economic Development Administration named BFTP/SEP's Technology Commercialization Group (TCG) one of four national finalists for the 2009 Excellence in Economic Development Awards. BFTP/SEP's CEO is an inaugural member of President Obama's National Advisory Council on Innovation and Entrepreneurship, led by U.S. Department of Commerce Secretary Gary Locke. This council recognized expertise provides a crucial core of knowledge, networks, and ideas that is not present in the university setting.

2. The NTI Management Structure

One of the NTI's key strengths is its carefully-structured and efficient management team. The NTI is led by its Oversight Committee (OC) and Operating Committee (OpCom). The OC members

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[6] R. GEIGER & P. HALLACHER, NANOTECHNOLOGY AND THE STATES: PUBLIC POLICY, UNIVERSITY RESEARCH, AND ECONOMIC DEVELOPMENT IN PENNSYLVANIA (2005) (Report to the National Science Foundation, NIRT:0403783); T. Armstrong, *NANOMICS: The Economics of Nanotechnology and the Pennsylvania Initiative for Nanotechnology*, 16 PENN ECON. REV. 1 (2008); Creso M. Sá et al., *Universities and State Policy Formation: Rationalizing a Nanotechnology Strategy in Pennsylvania*, 25 REV. POL'Y RES. 3 (2008).

[7] PENNSYLVANIA ECONOMY LEAGUE, A CONTINUING RECORD OF ACHIEVEMENT: THE ECONOMIC IMPACT OF BEN FRANKLIN TECHNOLOGY PARTNERS 2002-2006 (2009), http://economyleague.org/files/bftp_impact_full_FINAL.pdf (last visited Aug. 16, 2011).

[8] International Economic Development Council, IECD Excellence in Economic Development Awards, http://www.iedconline.org/Downloads/2008_Winners.pdf.

are the Vice Provosts for Research of Drexel University and the University of Pennsylvania, and the President and CEO of Ben Franklin Technology Partners of Southeastern Pennsylvania. As official representatives of the three founding institutions of the NTI, the OC brings the full weight of institutional commitment and endorsement to the NTI. The OC also serves as the advocate and liaison to other state government offices including the legislature to procure support for the NTI and its mission. The shared authority of two universities and the economic development agency is notable.

The day-to-day management of the NTI is conducted by the Operating Committee (OpCom), which reports directly to the OC. Its members have combined knowledge, and expertise in research, commercialization and business development. The OpCom consists of the two NTI Institutional Principal Investigators from the University of Pennsylvania and Drexel University, the Ben Franklin Technology Partners Director of the NTI, and the Director of the Nanotechnology Commercialization Group.

A key component within the NTI is the NANOTECHNOLOGY COMMERCIALIZATION GROUP (NCG). The NCG is a key innovative concept of the NTI, developed in recognition of the benefits of pooling nanotechnology intellectual property from many universities and providing a community technology transfer service with resources and expertise to promote the commercialization of that intellectual property. Armed with a single "Collaboration and Inter-Institutional Agreement" among all NTI institutions (which are explained below), the NCG provides industry and investors with a single point of contact for license negotiation, independent of the number of institutions with ownership of that IP. The NCG operates as an administrative unit of and is located within the University of Pennsylvania's Center for Technology Transfer but integrates the technology transfer activities of all thirteen-member research institutions. To enable the NCG to function, funds within the NTI's budget are specifically allocated for NCG staff within Penn and Drexel's technology transfer offices.

As a single repository of NTI's IP, the NCG is the starting place for interested companies to search for technology to license and, thereby, confers a valuable marketing advantage for all technologies in that pool. In addition, the centralized service from the NCG enables more resources to be dedicated to nanotechnology to support the development of greater expertise in that field than could be provided by individual universities. It also assists in identifying previously unknowable synergies between IP assets and developing multi-university collaborations with potential to perform useful research for industry. The NCG, along with BFTP/SEP, also facilitates the establishment of new companies or licensing of IP to existing companies, demonstrating the successful vision of the NTI. Staffed with two University of Pennsylvania employees and a Drexel University employee funded by the NTI core budget and matched with institutional support from the two universities, the NCG provides the following services for all NTI members:

- Manage IP disclosures, IP evaluation and patenting;
- Identify and market all nano-related IP among NTI institutions;
- Increase the potential of IP:
    - Identify IP packages resulting in increased potential,
    - Perform limited due-diligence,
    - Provide Proof-of-Concept funding (see below);
- Help investigators engage with industry partners;
- "One-stop shopping" for license agreements;
- Facilitate formation of start-up companies.

3. Legal Agreements

The success of the NTI is due, in large part, to its novel legal framework. The NTI is not a legal entity, but a "contractual collaboration" to fulfill the mission of the NTI. In addition to a series of Memoranda of Understanding (MOU) for the creation of the NTI, the creation of the NCG and the NTI's organizational structure, a novel legal agreement, the "Collaboration Agreement Inter-Institutional Agreement" was constructed with the intent to bind the NTI's Participating Institutions with regard to confidentiality and IP management and licensing procedures. This "top-down" agreement codifies actions with regard to:

1. INVENTION DISCLOSURES, including ownership of sole or joint inventions, which remain with the institution (the NTI is not a legal entity and does not have any ownership of NTI-funded IP); the concept of "IP Pools," where it is determined to be commercially advantageous to market and license more than one invention together.
2. LICENSING PROCEDURES for sole, joint and pooled inventions.
3. ROYALTY AGREEMENTS, in which the participating institutions pay to NTI a royalty based on any revenue generating activity (license, sales, etc.) relying on NTI-funded IP. This royalty is based on a pre-determined formula, exclusive of sunk costs and with a cap of 5 times the aggregate amount of NTI funding for the licensed invention, regardless of the funding level or timing of funding.
4. JOINDER AGREEMENTS, which allow new institutions to join the NTI. It is a condition of membership to sign the Collaboration Agreement.

4. Summary of Programs and Activities

The NTI's programs for technology development and commercialization are designed to exploit the technology capabilities resident among the NTI's constituent institutions and companies, as well as to anticipate trends. Over its history, the NTI has provided funds to support personnel and research in technology development, commercialization and outreach (Table 2).

A. Core Programs

This program supports multi-investigator, multi-institutional projects with awards in the $150,000 to $300,000 per year range. These projects require progress towards commercialization by moving a specific nanotechnology towards licensing or forming the basis for a start-up company.

Three Core Programs were funded in 2008-2010. The projects and the participating institutions are:

1. NANOSCALE CELLULAR PROBES to develop intracellular probes for in situ investigations (Penn, Drexel, Temple);
2. NANOCANTILEVER BIOSENSORS to develop enhanced assays for the detection of immune responses to chemotherapeutic agents to inform therapeutic decisions (Drexel, Fox Chase Cancer Center, Temple); and
3. NANOFIBROUS SCAFFOLDS FOR TISSUE ENGINEERING to develop new vascular grafts (Drexel, Penn, Children's Hospital of Philadelphia).

Each of these projects has resulted in new, multi-institutional IP and licensing opportunities or executed licenses. The Cellular Probe team's paper in *Nanotechnology*, "Cell Electrophysiology with

Carbon Nanopipettes" was made available by the publisher on-line and was determined to be the most accessed article in 2008.[9]

B. Ambassador Program

This program provides funding to university faculty, students, or research staff to train at industry or federal laboratories such as National Institute of Standards and Technology (NIST), the NanoCharacterization Lab at the National Cancer Institute, or federally-funded user facilities to learn skills and access techniques and instrumentation not available in their current institutions. This promotes more rapid leveraging of national resources for nanotechnology research at NTI member institutions, and reduces barriers for university-industry collaborations. Six projects were funded for training at NIST, Cornell Nanoscale Science and Technology Facility, Penn State Hershey, Ethicon (J&J), Kraton Polymers, Inc. and Gamry Instruments.

C. Joint NTI/CEET Program

The NTI created a new program by teaming with the University of Pennsylvania's Center for Excellence in Environmental Toxicology to co-fund two pilot programs addressing the critical environmental health and safety issues of nanotechnology through nanotoxicological studies (Table 2).

D. Commercialization Programs

Programs to support commercialization are managed by the Nanotechnology Commercialization Group. Support is provided through two Proof-of-Concept funds (PSTR and NAF), and a program that matches funds for nano-based Sponsored Research Agreements. These components each address critical gaps in technology advancement to commercialization.

i. Proof-of-Concept Funds

The NTI supports two key programs for proof-of-concept and translational research. The Program to Support Translational Research (PSTR) fund is designed to provide grants directly to institutional researchers to support projects with high potential for success. The NanoApplication Fund (NAF) provides loans to companies to support institutional research to advance the company's technology, and utilize revenue-partnership agreements.

ii. Program to Support Translational Research Fund (PSTR)

The PSTR fund provides financial support for studies recommended by the NCG to: (1) support seed-type projects focused on high-risk, high-reward research with a well-defined commercial target (Phase I projects); and (2) advance the development or demonstrate the commercial potential of recent inventions (Phase II projects). Awards are based on technical merit, feasibility, and an assessment of the commercial potential provided by the Corporate Advisory Group and other outside corporate reviewers. For higher funding levels, IP patentability and the potential to improve the technology's attractiveness for licensing or investment are the key factors of criteria. Twenty-two projects were funded during 2008-2010 and are shown in Table 2.

iii. Nano Applications Fund (NAF)

The NAF promotes the utilization of university resources by small or start-up companies to advance nano-related technologies. This program provides a means for driving commercialization of university IP by funding small Pennsylvania companies to commercially develop those inventions with assistance from university partners. The funding ensures commercial guidance in the development of the technology and also provides direct support for emerging small enterprises, up to $50,000, thereby contributing directly to economic development. Similar to the NIH Small Tech-

[9] Michael G. Schrlau et al., *Cell Electrophysiology with Carbon Nanopipettes*, 3(3) ACS NANO 563 (2009).

nology Transfer (STTR) program, which awards a grant to a small company to work with a university partner, it is encouraged that NAF funds are used to "subcontract" a university partner to co-develop commercially useful technologies. The NAF loan program is modeled on BFTP/SEP's royalty-based investments in emerging companies and provides for a success-based return to the NTI in the form of a revenue-partnership agreement. These funds are available to any Pennsylvania company, irrespective of whether their university collaborator resides at an NTI-affiliated institution.

Current NAF projects represent technologies in targeted drug delivery, prostate cancer detection, carbon nanotube-based supercapacitors, oil remediation, biodegradable polymers, diabetes control and nanoparticle inks (Table 3). Of particular note is the expectation of two companies to start paying off these loans in the coming fiscal year.

iv. Sponsored Research Agreements (SRA) Matching Funds

SRAs are typically grants provided to a Principal Investigator at a university by an industry partner to advance a technology specific to the company. The NTI provides matching funds for nano-based SRAs using a tiered system prorated by company location and size. The SRA matching funds provide incentives to drive university-industry collaborations and help lower commercialization hurdles. The SRA match program has been successful in fostering new SRA agreements. The additional technical assistance and market advice that the NTI provides during the SRA negotiating process creates incentives for both the industry and academic partners to come to the table and strike an agreement; often these opportunities are lost due to ineffective negotiations and other barriers to agreements.

Matching funds for ten active SRA projects ranging from $10,000 to $50,000 were approved in 2008-2010 (Table 3), including biomedical applications of nanophosphors, single molecule monitoring of protein nano-expression, printing RFID antenna using nanoparticle inks, homogenization methods for micromechanical modeling of nonlinear nanostructured composites, nanotribology in boundary film lubrication and block copolymer worm micelles for agricultural applications.

E. Outreach

The NTI, with support from NCG, organizes numerous outreach activities including annual NanoSymposia and NanoForums. The NCG's Lab-to-Market forum showcases nanotechnologies from its member institutions ripe for commercialization to the business and venture community, which has led to subsequent commercialization agreements. The NTI continues to be a leading advocate in the promotion of nanotechnology commercialization through participating and contributing to national and international events. As an active member of the NanoBusiness Commercialization Alliance, the nation's largest organization (of researchers, business and investors) dedicated to nanotechnology, the NTI has been continuously participating in the organization's annual policy tour in Washington, DC.

F. Results

The payoff from these activities is seen in the accelerated outcome over the past three years that is summarized in the tables below. NTI's productivity in the years from 2008 to 2010 in terms of the number of new IP assets, technology licenses and new company spinoffs has exceeded cumulatively all activities in the previous seven years (Table 4). The NTI has contributed significantly to regional economic growth as measured by jobs created/retained (more than 130) and businesses assisted (43). NTI companies and researchers secured over $2 million in private capital during this same period. These numbers compare favorably and even exceed those from many of the region's major research institutions as shown in Table 5. The NTI also compares favorably to the major

Proof-of-Concept Centers highlighted in the 2008 Kauffman report,[10] the von Liebig Center at UC San Diego,[11] and, in particular the Deshpande Center at MIT (Table 6).[12] While these two centers are not focused on a single technology, it is still informative to compare the successes of each to that of the NTI. These results reflect the maturation of nanotechnology in general and increased funding for nanotechnology at the member institutions, and also confirm the success of the NTI model in particular.

i. Integration with State, Regional and Federal Programs

The NTI continues to leverage its national reputation through increased integration into state, regional and federal programs.

The hallmark of a successful new initiative lies in its ability to adapt and evolve, and to complement and inspire other programs. In this manner, the NTI has succeeded as well. Its accomplishments became the impetus for the Commonwealth of Pennsylvania's Department of Community and Economic Development to provide $2.2M for the creation of and continued funding of the Energy Commercialization Institute, which is based upon similar principles and practices as the NTI. The NTI model is also being incorporated on a much larger and broader scale as the single IP management and commercialization component of the recent award of $130M by DOE to create the Greater Philadelphia Regional Innovation Cluster for Energy Efficient Buildings, that involves over 22 members and over 90 affiliated partners.

The NTI partners with and often co-funds projects with most of the region's existing and new Proof-of-Concept programs:

- Technology Commercialization Loan Fund from BFTP/SEP;
- QED Program from the University City Science Center;
- Wallace Coulter Foundation Translational Partners Grant Program at Drexel University;
- Innovator's Fund at Fox Chase Cancer Center;
- DOE GPIC Opportunity Research Fund.

All of these activities are consistent with and indeed were anticipated in the March 2010 "Report to the President and Congress on the Third Assessment of the National Nanotechnology Initiative (NNI),"[13] and the resulting "Draft NNI Strategic Plan" released in November 2010.[14] In this comprehensive review of the NNI, specific recommendations included the focus on accelerated

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[10] C. GULBRANSON & D. AUDRETSCH, PROOF OF CONCEPT CENTERS: ACCELERATING THE COMMERCIALIZATION OF UNIVERSITY INNOVATION (2008), *http://sites.kauffman.org/pdf/POC_Centers_01242008.pdf* (last visited Aug. 16, 2011).

[11] *See generally,* UC San Diego Jacobs School of Engineering, William J. von Liebig Center for Entrepreneurism and Technology Advancement, http://www.vonliebig.ucsd.edu/ (last visited Aug. 16, 2011).

[12] *See* Deshpande Center, *http://web.mit.edu/deshpandecenter/about.html* (last visited Aug. 16, 2011).

[13] *See* PRESIDENT'S COUNCIL OF ADVISORS ON SCI. AND TECH., REPORT TO THE PRESIDENT AND CONGRESS ON THE THIRD ASSESSMENT OF THE NATIONAL NANOTECHNOLOGY INITIATIVE (2010), *http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nano-report.pdf* (last accessed Aug. 18, 2011).

[14] *See* COMM. ON NANOSCALE SCI., ENG'G, AND TECH., NAT'L SCI. AND TECH. COUNCIL, DRAFT FOR PUBLIC COMMENT DECEMER 6, 2010 NATIONAL NANOTECHNOLOGY INITIATIVE ENVIRONMENTAL, HEALTH, AND SAFETY RESEARCH (2010), *available at* http://strategy.nano.gov/wp/wp-content/uploads/2010/12/DraftEHSstrategy-17Dec2010-to-post.pdf (last accessed Aug. 18, 2011).

technology transfer, commercialization, creation of public-private partnerships with a focus on nanomanufacturing, commercialization and job creation—all activities envisaged by the NTI at its inception.

ii. Discussion: Lessons Learned

Since its inception in 2000, the NTI has continued to innovate as it develops and evolves. Programmatic changes occur in the context of continuous feedback from its stakeholders: the research institutions, our corporate partners and collaborators, our Corporate Advisory Group, the investment community and the public. As with all new and disruptive technologies, the NTI began its mission with an emphasis on early-stage, high-risk projects. This reflected the reality of the nascent state of nanotechnology: the lack of early stage funding even from the major funding organizations such as NSF and NIH, and the lack of a commercial market. In the past two years, we have greatly enhanced the role of external review of submitted proposals, both from industry and academia. This has provided critical assistance and insight in selecting the most promising projects for funding. It has proven remarkably valuable to the investigators by providing constructive feedback on their technologies and proposed approaches.

Ten years later, the maturation of the NTI can be seen in the acceleration of its commercially oriented programs in lockstep with the emergence of early stage funding opportunities through government and foundations. In addition, the NTI's ability to manage and market its IP and commercialize its technology is in synchrony with the emergence of a commercial market for these projects. Significant emphasis on outreach through programs and symposia help assure a talented workforce and an educated public. The NTI recognizes the importance of identifying and securing new sources of funding to maintain sustainability. To that extent, the NTI is an active participant in several grant applications to NIH, NSF and DOE as well as to foundations who focus on innovation. No different than the semiconductor or biotechnology industries, we are now at the acceleration stage of nanotechnology development and the NTI is committed to remaining at the forefront.

III. Innovation and Effectiveness

The NTI is a groundbreaking organization with a continuous mission to promote the acceleration of emerging disruptive nanotechnologies into the commercial market. The NTI's track record has been validated by its performance: the NTI has exceeded all its goals and deliverables, which include tangible successes in commercialization and job creation. The NTI's vision has been supported and complemented by:

- The vision of its founding partners that breaking down traditional institutional barriers to cooperation will have a synergistic effect on transforming emerging technologies to reality;
- The unique organizational and legal structure, in which research institutions recognize the value of collaboration vs. insularity to achieve a greater, common benefit;
- The unique organizational and legal structure that allows for adaptation, evolution and expansion.

The NTI model and its accrued results has succeeded while the outcomes of current federal funding for translational research, proof-of-concept and public-private partnerships have been mixed.[15] Furthermore, the significant increase in NTI activities is forcing the capital markets to take

[15] Block & Keller, *supra* note 4; A. Link & J. Scott, *Government as Entrepreneur: Evaluating the Commercialization Success of SBIR Projects,* 39 RES. POL'Y 589 (2010); COMM. FOR CAPITALIZING ON SCI., TECH., & INNOVATION,

notice, with an increase in venture capital to the region. The success of the NTI has been recognized nationally, and specifically identified as a model effort for the Philadelphia region by the CEO Council for Growth's 2007 study on "Accelerating Technology Transfer in Greater Philadelphia"[16] and in the 2010 Greater Philadelphia Regional Report.[17] Most recently, the NTI was selected as a 2011 Honorable Mention for the Partnership with Educational Institutions Award from the International Economic Development Council.

The commitment to improving the lives of the residents of Southeastern Pennsylvania and beyond is manifest in the programs the NTI has created and supported. The number of partnerships, collaborations and joint programs between the NTI and the regional community and the resources required to service all these programs are substantial and rarely found. It involves an extensive commitment from within each member organization and its regional stakeholders. This commitment is also financial: The faculty involved in leading the NTI sacrifice significant time from their other responsibilities to provide the needed commitment, and the organization partners provide significant matching funds (over $4M in *cash* matching from the NTI's founding members since 2006) and other resources.

Challenges to the successful implementation of the programs are equally daunting. It requires vision, skill, a facility to balance parochial interests and common goals among partners and stakeholders, and the ability to communicate effectively. Most importantly, it requires a knowledge that the work being done is important. By successfully fostering multiple successful agreements, partnerships, and collaborations between the different organizations involved — all leading to tangible results involving the commercialization of nanotechnology research — the NTI has met these challenges. In doing so, the NTI serves as a leader in the successful commercialization of emerging technologies to benefit the economy of the region.

However, the NTI and other unique enterprises like it are threatened by the reliance on state funding and the lack of access to federal funding opportunities; in many cases, it is an ineligible applicant for the few federal programs that are available. Furthermore, the intrinsic constraints of state-based funding inhibit interactions with highly promising nearby partners who happen to reside across state lines. Taken together, an untold number of missed opportunities for high-tech economic development exist that ultimately diminish the competitiveness of the United States' economy.

The NTI supports and provides real solutions to barriers to the successful commercialization of innovative technologies. The recognition of that success demonstrates how the NTI model can serve as a template for new programs and new initiatives in new technology sectors. The NTI serves as a successful, integrated model for promoting the commercialization of federally-funded university research and thereby boosting its value, turning federal funding into an investment with substantial payoffs. Furthermore, it demonstrates the tangible value of proof-of-concept centers. In fact, this is what the NTI *is*.

NAT'L RESEARCH COUNCIL, AN ASSESSMENT OF THE SBIR PROGRAM AT THE NATIONAL INSTITUTES OF HEALTH (Charles W. Wessner ed., 2009), *http://www.ncbi.nlm.nih.gov/books/NBK11455/pdf/TOC.pdf* (last visited Aug. 16, 2011).

[16] *See* CEO COUNCIL FOR GROWTH, ACCELERATING TECHNOLOGY TRANSFER IN GREATER PHILADELPHIA (2007), *http://www.selectgreaterphiladelphia.com/pdfs/Technology_Transfer_1C690E.pdf* (last visited Aug. 16, 2011).

[17] *See* SELECT GREATER PHILADELPHIA, GREATER PHILADELPHIA 2010 REGIONAL REPORT (2010), *http://www.selectgreaterphiladelphia.com/SGP_Report2010_flip/index.html* (last visited Aug. 16, 2011).

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Table 2. Projects Funded (2008-2010)

TECHNOLOGY SECTOR		PROJECT NAME
LIFE SCIENCES	Probes	Nanoscale Cellular Probes
		Automated and Electronically-Controlled Nano Pipet for a Novel 2-D Membrane Electrophoresis
	Sensors	Array Piezoelectric Nanocantilever Sensors
		Automated Microliter ImmunoSorbent Analysis
		An Inexpensive Miniaturized Device for Detecting Breast Cancer Cells in Biopsy Samples
		Label Free Biosensor Array Based on AIN Nanomechanical Device
	Delivery	Antibody-Functionalized Carbon Nanotube Transistors as Biosensors for the Detection of Prostate Cancer
		Ultrasound-Assisted Drug Delivery from Nano Contrast Agents for Advanced Liver Cancer
		Surface-Enhanced Raman Scattering (SERS) Substrate Filters for Detection of Air-Borne Toxins
		Targeted Nanoparticles for Intracellualar Cancer Therapy
	BioMaterials	Nanofibrous Scaffolds for Tissue
		Assessment and Optimization of Fabrication Process Parameters for the Control of Nanoscale Porosity in Novel Bioactive Glass Scaffolds for Biomedical Applications
		Nanostructured Bactericidal Sol-Gel Thin Films on Percutaneous Orthopedic External Fixator Pins
		Flexible Organic Transistors for Physiological Sensing and Stimulation: A New Generation of Implantable Devices
		Nanoconjugates for Targeted Treatment of Acute Lung Injury
	Nanotoxicology	Toxicology of Bare and Coated Superparamagnetic Iron Oxide Nanoparticles for Vascular Applications
		Evading Macrophage Clearance of Nanoparticles by Functionalizing with 'Marker or Self' Protein CD47
NANOMATERIALS	Materials	Large-Scale Purification of Carbon Nanotubes by Dynamic Annealing
		Carbon Nanopipettes with Metal-coated Tips
		Low-Temperature Mechanical Reinforcement of Nanoparticle Thin Films
	Devices	A Solid State Drive Memory Prototype
	Water	Optical Dipstick for Heavy Metal Ion Detection
		Frac Water Analysis
		Nano-enhanced Plastic-Based Cementitious Material

Table 3. Corporate Projects Funded 2008-2010

TECHNOLOGY SECTOR	COMPANY NAME	LOCATION	FUNDING FORM
LIFE SCIENCES	Anima Cell Metrology	Bernardsville NJ	SRA match
	CFD Research Corporation	Huntsville AL	SRA match
	Keystone Nano	State College PA	NAF Loan
	Leversense	Newtown Square PA	SRA match
	Sunstones Biosciences	Philadelphia PA	SRA match + NAF Loan
	ATRM (a division of J&J)	Raynham MA	SRA match
PHYSICAL SCIENCES	Exxon Mobil	Annandale NJ	SRA match
	FMC Corporation	Philadelphia PA	SRA match
	Lockheed Martin	Cherry Hill NJ	SRA match
	PChem Associates	Bensalem PA	NAF Loan
	Rhodia	Bristol PA	SRA match
	SFC Fluidics	Fayetteville AR	SRA match
	Syngenta	Munchwilen Switzerland	SRA match
ENERGY	Nano Blox	Clarion PA	NAF Loan
	PA Sustainable Technologies	Lehigh PA	NAF Loan
	pChem	Bensalem PA	NAF Loan
	Polymer Phases	Bristol PA	NAF Loan
	Y-Carbon	King of Prussia PA	NAF Loan

Table 4. NTI Metrics

CATEGORY	2000 - 2006	2007	2008-10
New Disclosures	80*	89*	215
Patent Applications			180
Issued Patents			21

Licenses (including Option)	7	5	26
Start-Up/Spin-Out	10	1	14
Jobs Created/Retained	NR**	NR	132
Businesses Assisted	NR	NR	43
Follow-on Funding/Leverage	$150M	$9.4M	$95.6M

**IP Assets not broken out during this time period*

***NR = Not Reported*

Table 5. NTI Impact Analysis[18]

INSTITUTION	TOTAL RESEARCH DOLLARS (2008 – 2009)	IP APPLICATIONS	ISSUED PATENTS	LICENSES	START-UPS
Drexel University	$206,040,000	171	22	35	7
Lehigh University	88,583,000	24	0	0	0
Penn State University	1,465,037,000	200	72	47	4
Temple University	238,837,000	15	5	1	1
University of Pennsylvania	1,430,836,000	995	85	116	6
NTI (2008-2010)	3,500,000	180	21	26	14

[18] Association of University Technology Managers, Annual Survey, *http://www.autm.net/Surveys.htm* (data from 2008 and 2009).

Table 6. Comparison with National Proof-of-Concept Centers[19]

	VON LIEBIG CENTER	MIT DESHPANDE CENTER	NTI
Location/affiliation	Jacobs School of Engineering, UCSD	School of Engineering, MIT	13 Southeastern PA Research Institutions + BFTP/SEP
Initial funding	$10,000,000	$17,500,000	$9,000,000
Source	Gift from the von Liebig Foundation	Gift from Jaishree and Guraraj Deshpande	PA Department of Community and Economic Development
Grant sizes	Seed Grants: $15,000 - $50,000	Ignition Grants: up to $50,000; Innovation Grants: up to $250,000	Up to $120,000 for individual projects; $750,000 for multi-institutional projects
Number of funded proposals	82	80	85
Total amount of grants awarded	$4,600,000	$11,000,000	$16,744,492
Number of licenses	>6	>20	48
Number of start-ups	26	23	31
Number of jobs created/retained	>180	>400	>130

[19] PENNSYLVANIA ECONOMY LEAGUE, *supra* note 7; GULBRANSON & AUDRETSCH, *supra* note 10; UC San Diego Jacobs School of Engineering, *supra* note 11; Personal communications from Raj Melville, Deshpande Foundation; Personal communications from Rosibel Ochoa, UCSD.

Figure 1. NTI in a Box

Commercialization of innovative research is inefficient with significant lost potential:

- Barriers to the transfer of intellectual property to the market are well recognized.
- Existing programs fall short because they are not organized systemically to leverage the advantages of an innovation cluster.
- Barriers to success also include:
  - Lack of commercialization expertise at many research institutions where innovative technology is born;
  - Lack of access to enough seed-stage and early-stage venture capital;
  - Lack of management talent, workforce talent and industry-specific talent to create local companies;
  - Lack of a systematic innovation partnership between the federal government and state and local governments;
  - Lack of a "critical mass" of supportive individuals and business in these tech areas; and
  - Current economic environments and shifts in technology development pathways.

The Nanotechnology Institute (NTI) addresses each of these challenges and lays the foundation for an integrated, adaptable structure that can respond to future challenges by:

- Catalyzing and supporting industry-university research partnerships;
- Expanding regional innovation-promotion for technology commercialization and entrepreneurial support;
- Encouraging technology adoption by assisting small and mid-sized companies in implementing these new technologies;
- Supporting regional industry clusters through new grant proposals and access to capital;
- Building a sustainable community of innovation and economic growth;
- Integrating into established national priorities for economic development; and
- Serving as a model of innovation.