IDA

SCIENCE & TECHNOLOGY POLICY INSTITUTE

Department of Energy Technology Maturation Programs

Susannah V. Howieson
Elaine M. Sedenberg
Brian J. Sergi
Stephanie S. Shipp

May 2013

Approved for public release; distribution is unlimited.

IDA Paper P-5013

Log: H 13-000542

IDA SCIENCE & TECHNOLOGY POLICY INSTITUTE
1899 Pennsylvania Ave., Suite 520
Washington, DC 20006-3602

About This Publication

This work was conducted by the IDA Science and Technology Policy Institute under contract NSFOIA0408601, Task STPI-0400.00.AK (TP-20-1000), "An Examination of Department of Energy Technology Transfer Initiatives," for the Office of Science and Technology Policy. The views, opinions, and findings should not be construed as representing the official position of the National Science Foundation or the Office of Science and Technology Policy in the Executive Office of the President.

SCIENCE & TECHNOLOGY POLICY INSTITUTE

IDA Paper P-5013

Department of Energy Technology Maturation Programs

Susannah V. Howieson
Elaine M. Sedenberg
Brian J. Sergi
Stephanie S. Shipp

Executive Summary

Many promising early-stage technologies developed at Department of Energy (DOE) national laboratories require “maturation” in the form of additional development, testing, or prototyping before companies are willing to invest in them for commercial purposes. This paper contains ideas for DOE laboratories interested in implementing or refining their technology maturation programs and concludes with options for developing a DOE-wide technology maturation fund.

The White House Office of Science and Technology Policy (OSTP), in conjunction with the Department of Energy Technology Transfer Coordinator, asked the IDA Science and Technology Policy Institute (STPI) to examine the history of technology maturation programs and funding at the DOE and its national laboratories. The purpose was to document the types and characteristics of projects funded, the criteria to select the projects, and the metrics to track the success of these projects. OSTP was also interested in whether stakeholders supported technology maturation for DOE basic science programs.

Study Questions and Methods

Technology maturation programs provide a link between laboratory research and development products and specific market needs. Although applied research is more likely to result in science and technology suitable for commercialization, basic research, particularly use-inspired basic research, can also ultimately lead to commercial applications.

For any laboratory invention, additional development or testing may be necessary before an outside party is willing to license the intellectual property (IP) and commercialize the technology. If funds are devoted to advancing the development of nascent technologies, private industry is more likely to be willing to license the IP, thus bringing federally funded research to the private sector. This type of directed development may involve a partnership between the inventor (or technical team) and experts from private industry with insight into market needs and opportunities.

To better understand technology maturation programs past and present, this study considers the following questions:

- What is the history of technology maturation funding at the DOE and its laboratories?
- What are the design characteristics of successful technology maturation programs?
- What are the benefits of technology maturation programs?
- Should technology maturation programs be used to accelerate development of basic science programs at the DOE?

STPI researchers conducted a review of relevant academic literature and government documents and interviewed 28 individuals from DOE headquarters and the national laboratories. In addition, STPI researchers spoke with technology transfer representatives at seven universities with technology maturation programs to identify insights that could apply to the DOE.

Through this research, STPI researchers found examples of DOE technology maturation programs at both the department level and the laboratory level. In addition, universities have programs that are used to fund technology maturation. They provide examples and ideas for DOE laboratory technology maturation programs.

DOE Department-Level Technology Maturation Programs

Laboratory Technology Research Program

Between 1992 and 2004, the Office of Science's Laboratory Technology Research (LTR) program provided funding for medium- to high-risk, cost-shared collaborative research projects in the areas of advanced materials, intelligent processing/ manufacturing research, and sustainable environments that supported DOE missions and had commercial potential. Each research project had a defined scope, work plan, budget, schedule, and contract for a formal collaboration between the laboratory and a company. The funding peaked in FY 1995 and subsequently declined until the program ended in FY 2002.

LTR projects were selected based on the scientific and technical quality of the proposal, the qualifications of the principal investigator and facilities, the work plan, the commercial and technological potential, and the industry partner's participation. The partnership required at least one national laboratory partner and one (or more) industry partners that would match DOE funding through either in-kind support, funds-in support, or a combination of the two.

The LTR program ended in 2004 when Congress became divided over the role of public-private partnerships. According to a survey, industry participants considered the LTR program to be a success.

Technology Commercialization Fund

Congress initiated another DOE-level technology maturation program through the Energy Policy Act of 2005 (Public Law 109-58). The act specifies that 0.9% of funds allocated for DOE applied energy research, development, and demonstration shall be used to develop technologies for commercialization. The DOE Office of Energy Efficiency and Renewable Energy (EERE) responded by organizing the Technology Commercialization Fund (TCF) in 2007. The TCF was designed to complement angel or venture capital investment in early-stage corporate product development. The fund totaled almost $14.3 million for 2 years in FY 2007 and 2008. According to EERE staff, TCF brought together industry and the DOE's national laboratories to identify promising technologies facing the commercialization valley of death.

TCF projects focused on prototype development, demonstration, and deployment rather than further scientific research. Proposals were evaluated on the potential market opportunity, the likelihood of commercial success, the management team, alignment with DOE priorities, and interest by private sector partners. Industry partners were required to share costs 50/50 with the laboratories to demonstrate market interest in a technology. Eight DOE laboratories received funds that they used to partner with over 50 companies to advance laboratory technologies to the market.

DOE Laboratory-Level Technology Maturation Programs

Several DOE laboratories have established their own technology maturation funds. These provide funding on the order of $25,000 to $400,000 to move early-stage technologies to proof-of-concept or prototype stages with the hope of attracting potential licensees or investors. Awards are given to achieve a specific milestone or set of milestones. Most programs were initiated during the last decade as a result of the increased interest in accelerating the transfer of technologies from Federal laboratories. Several programs originated about 4 to 5 years ago in response to a shrinking economy and disappearing venture capital funds.

Total DOE laboratory-managed maturation funds range from $200,000 to $600,000 per year. Most laboratories use some portion of revenues from royalties, generally 25% to 35%, to fund their technology maturation or innovation funds. In addition, some states provide additional funds for technology maturation through proof-of-concept funds or technology acceleration funds.

Projects are selected by panels of experts (such as venture capitalists and investors) from outside the laboratory or by representatives within the laboratory. For example, one laboratory works with entrepreneurs and angel investors to choose technologies to receive maturation funds. At other laboratories, a panel of internal and external experts selects the proposals. At still other laboratories, laboratory directors, technology transfer office representatives, or other staff members select projects to receive technology maturation funds. In general, projects are more likely to be funded if the proposal provides evidence of industry interest in the technology.

Laboratories each fund 2 to 15 projects per year and most individual awards range from $50,000 to $100,000. Three laboratories fund projects up to $250,000 to $400,000 if they involve expensive equipment, scale-up, or demonstration. The demand for technology maturation exceeds the supply of funds. Many of the DOE laboratory representatives said that they are only able to fund about half the projects that could benefit from technology maturation funding.

DOE laboratories track the success of projects that receive technology maturation funds using a variety of short- to mid-term metrics such as the number of licenses, the amount of license revenue, and leveraging of additional funding. They also track success using longer term metrics, such as the number of start-ups, successful entry of products to market, and creation of jobs. Monitoring projects over the lifecycle of the technology is challenging since it may take many years for a technology to commercialize and have an impact. The following table describes the characteristics of DOE laboratory technology maturation programs.

Characteristics of DOE Laboratory Technology Maturation Program

History	Most within the last decade; many established 4 to 5 years ago
Types of projects funded	Proof of concept, prototype, scale-up, demonstration, additional data
Criteria and selection process	Formal proposals or informal submission Technological and commercial viability, potential impact Panels of experts (such as venture capitalists and investors) from outside the laboratory or by representatives within the laboratory
Size, quantity, and length of projects	$25,000 to $400,000 per project; most are $50,000 to $100,000 2 to 15 projects per year
Amount and source of funding	$200,000 to $600,000 per year Royalties (25% to 35%), state funding, fees
Tracking success	Licenses, license revenue, additional funding, start-ups, commercial products, job creation

University Technology Maturation Programs

The goal of university technology maturation programs is similar to that of national laboratories: to move technology closer to licensing or creating a start-up. Universities would like to move technologies off the shelf to stimulate economic growth in their regions. The impetus for one university biotechnology maturation fund came from the state government's recognition of the gap between university discovery and company adoption. Some universities have had maturation funds for the last 10 to 20 years; others have created programs more recently.

University maturation programs usually distribute funds either through an annual request for proposals or, more commonly, an open call from the technology transfer office. The selection criteria focus on a combination of technical validity and commercial potential and the need to advance the technology to the next milestone. Although most programs do not require that researchers with maturation proposals find co-sponsors, several assess the principal investigator's awareness and identification of potential commercial applications. Most programs involve representatives from the university research community to assess technical validity and commercial investors and entrepreneurs, or technology transfer representatives, to assess the market viability.

Projects funded through university maturation receive from $5,000 for answering targeted market questions up to $1 million for multi-year research efforts. The majority of projects range from $25,000 to $100,000. One program funds early-stage "ignition" grants with $50,000 to $100,000 for 1 year and more advanced "innovation" proposals with up to $250,000 for an additional year. Although most projects are funded for 1 year, some are provided awards for up to 2 years. One university program is beginning to offer multi-year awards.

Most of these programs fund 6 to 12 projects each year. One program with a small base of funding supports 2 to 4 projects a year, and another gives about 20 awards a year. The technology maturation program managers noted that they would fund double the number of projects if there were no funding constraints.

University maturation funds range in size from $200,000 to $2 million for funding projects per year, with most universities falling into the $500,000 to $1 million range. Universities obtain funding from philanthropic sources, university alumni, state economic development funds, internal university or endowment funds, and licensing royalties. Some universities use multiple sources to fund their technology innovation program.

University-managed technology maturation funds measure success by a project's ability to reach the marketplace, the number of licenses and start-ups, and the extent of follow-on funding. Some also follow projects to better understand how to redirect their investments by assessing lessons learned. The following table describes the characteristics of university technology maturation programs.

Characteristics of University Technology Maturation Program

History	Some for past 10 to 20 years, most established in last 2 to 5 years
Types of projects funded	Proof of principal, additional development, validation studies, enhance intellectual property positions Some oriented towards a particular field
Criteria and selection process	Annual request for proposals or open call Combination of technical validity and commercial potential University representatives to assess technical validity; commercial investors, entrepreneurs, or technology transfer representatives to assess market viability
Size, quantity, and length of projects	\$5,000 up to \$1 million; majority are \$25,000 to \$100,000 6 to 12 projects per year 1 to 2 years
Amount and source of funding	\$200,000 to \$2 million; most are \$500,000 to \$1 million Philanthropy, state funding, internal university, or endowment; only one used royalties
Tracking success	Licenses, start-ups, follow-up funding, commercial outcomes

Support for Technology Maturation Funding across the DOE

Although many DOE laboratories have initiated their own technology maturation programs, supporting technology maturation across the DOE, particularly within basic science programs, is still a controversial topic. Arguments against technology maturation include the assertion that the products of DOE basic research laboratories, such as those found in the Office of Science, are too far removed from the market to justify funding their advancement. One DOE official interviewed for this study noted, however, that implementing the DOE's overall mission "to ensure America's security and prosperity" would not be possible unless laboratory technologies ultimately reach the market.

Other individuals interviewed outlined how the DOE and laboratory programs (including the LTR and TCF) were beneficial to the DOE and the nation as a whole. The core benefit, according to these individuals, is that it increases the number of technologies that are brought to market. These programs provide the incentives for DOE laboratories to actively partner with industry, which facilitates interaction with industry experts and helps researchers and staff think about potential uses of their technologies. It also promotes understanding of commercial impact. Interviewees also noted that DOE laboratory researchers conduct world-class science. Programs that support maturation of research, including basic research, offer a unique opportunity for these researchers to solve real-world problems. According to one interviewee, a maturation investment that is unsuccessful in bringing a technology to market still benefits the DOE by providing greater understanding of market need and the direction of future investment.

Design Options for a DOE Technology Accelerator Fund

One way the DOE could help laboratories accelerate technology transfer would be to identify other sources of technology maturation funds, such as state funding Alternatively, establishing a DOE Technology Accelerator Fund could augment existing technology maturation funds available to DOE laboratories.

The fund could help mature the technologies to the point that companies are interested in developing them further for commercialization. To be most effective, the fund could be open to all science and technology topics in DOE mission areas. The fund could provide support for research targeted to commercial needs, prototype or proof-of-concept development, collection of additional data, scale-up, or demonstration.

Other features of a technology maturation program funded by the DOE might be:

- A name that conveys excitement and markets the program inside and outside the DOE
- Management at either the DOE program or laboratory level
- Clearly defined criteria and a competitive selection process
- Modest funding requirements
- Well-defined metrics to track success

Conclusion

DOE technology maturation programs have evolved from DOE-funded programs first established 20 years ago to be supplanted recently by programs emerging at the laboratory level. These programs provide additional development necessary to move early-stage technologies to a point where the private sector can make the investments to turn them into commercially viable products. Such programs can encourage laboratory researchers to think about the market potential early in the development cycle, lead to income for the laboratory, and spur economic development. Because the timelines for these developments are long (ranging from 2 to 30 years), providing a steady stream of technology maturation funding will increase the flow of inventions from the laboratory to innovations in the marketplace.

Contents

A. Introduction

The mission of the Department of Energy (DOE) is "to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions."[1] The unique abilities of the DOE national laboratories advance this mission by producing an array of novel technologies, processes, materials, and methods that advance energy and environmental research. The Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480) mandated that DOE and other agencies implement processes and mechanisms to transfer their science and technology to the commercial market. Since then, the DOE has established technology transfer offices and developed mechanisms to transfer novel technologies to the private sector. However, many nascent technologies conceived in the DOE laboratories require additional work before industry is willing to invest in their further development.

The White House Office of Science and Technology Policy (OSTP), in conjunction with the DOE Technology Transfer Coordinator, asked the IDA Science and Technology Policy Institute (STPI) to study technology maturation programs at the DOE and the DOE laboratories. OSTP was also interested in whether there was support for technology maturation within DOE basic science programs.

1. Rationale for Technology Maturation Funding

Moving science and technology developed in laboratories to market is challenging for several reasons. According to a recent Government Accountability Office (GAO) report, "[T]he pathway from laboratory bench to commercial product is complex, involving numerous and sometimes difficult steps, the process can derail at any point and products may not always reach, or find success in, the marketplace" (GAO 2009, 6). The process of moving a new concept from laboratory bench to general acceptance by industry also typically takes longer than expected (Redwine and Riddle 1985).

For any laboratory invention, additional development or testing may be necessary before an outside party will be willing to license and commercialize the technology. "[P]otential industry partners are often reluctant to assume the risks of investing in technologies whose potential has not been demonstrated with a prototype, performance data, or similar evidence" (GAO 2009). "The chasm between the immature state of the work emerging from the research laboratory and the level of maturity needed to attract a large corporate transferee was identified, as one of the largest barriers to technology transfer" (Wang et al. 2003). Some technologies get trapped in this "valley of death"

[1] See http://energy.gov/mission.

because maturation funds are lacking for the additional development they require before they are commercially viable.

Technology maturation funding programs are designed to bridge this gap by providing a link between laboratory research and development (R&D) products and specific market needs. This type of directed development can involve a partnership between the inventor (or technical team) and experts in private industry with insight into market needs and opportunities. However, there is often a shortage of funding and lack of researcher incentives to undertake this phase of research (Branscomb and Auerswald 2002). Despite a widespread belief to the contrary, most funding for technology development for the invention-to-innovation transition does not stem from venture capitalists (VCs), but from individual private equity “angel” investors, corporations, and the Federal government (Auerswald and Branscomb 2003). If funds are devoted to advance the development of nascent technologies, private industry is more likely to be willing to license the IP, thus bringing federally funded research to the private sector. Even projects that do not result in successful deployment of technology create opportunities for researchers to learn more about specific applications of their research (Barr et al. 2009).

2. Study Approach

This report explores answers to the following questions:

- What is the history of technology maturation programs at the DOE and its laboratories?
- What are the design characteristics of technology maturation programs?
- What are the benefits of technology maturation programs?
- Should technology maturation programs be used to accelerate development of basic science programs at the DOE?

Past DOE programs designed to address funding needs at the maturation stage of R&D include the Laboratory Technology Research program and the Technology Commercialization Fund. STPI researchers examined these two examples of DOE as well as university technology maturation programs for comparative insights. The STPI research team interviewed 28 individuals about past and present DOE technology maturation funds, and spoke with technology transfer coordinators at seven universities with technology maturation funds. (Appendix A provides a list of interviewees, and Appendix B contains the interview discussion guide). In addition, the STPI team reviewed the academic literature and government reports on challenges associated with technology transfer and technology maturation.

Based on findings from the interviews and the literature review, this paper describes the justification for and design of technology maturation programs at DOE headquarters and its national laboratories. The sections that follow explain various features and benefits of the past technology maturation programs at the DOE (section B), current local DOE laboratory programs (section C), and a select number of university programs (section D). Section E provides ideas for laboratories interested in implementing or refining their maturation funding programs and describes design options for developing a DOE-wide technology maturation funding program. Conclusions are presented in Section F.

B. Past DOE Technology Maturation Programs

DOE has had a number of successful technology maturation programs. Two examples follow.

1. DOE Office of Science Laboratory Technology Research Program

The National Competitiveness Technology Transfer Act of 1989 (Public Law 101-189) authorized the DOE Office of Science Laboratories to engage with industry to further develop technologies for transfer to the private sector. The Laboratory Technology Research (LTR) Program ran from 1992 to 2004. In 1992, LTR serviced five DOE Office of Energy Research (DOE/ER)[2] multi-program laboratories: Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL). In 1999, the single program facilities Ames Laboratory, Fermi National Accelerator Laboratory, Princeton Plasma Physics Laboratory, Stanford Linear Accelerator, and Thomas Jefferson National Accelerator Facility, were also included in the LTR program.

The LTR program mission was "to advance science and technology, in support of DOE missions, toward innovative applications through cost-shared partnerships with the private sector" (DOE 1998). According to program participants, industry gained access to world-class researchers and facilities, while the laboratory researchers leveraged the expertise and participation of industry (Payne and Kniel 2000). The program offered support to pursue technology research with potential value to industry, complement basic research goals of the laboratory, and "enhance public benefit from investment in science research at the national laboratory" (DOE 1997).

The LTR program supported medium- to high-risk, cost-shared collaborative research projects that had commercial potential and supported DOE missions. Each research project had a defined scope, work plan, budget, schedule, and contract that

[2] DOE/ER is now called the DOE Office of Science.

outlined a formal collaboration between the laboratory and a company. The program had three focus areas: advanced materials, intelligent processing/manufacturing research, and sustainable environments. According to program rules, no Federal funding moved from the DOE to private industry through the LTR program. Industry partners were required to match DOE funds to the project or provide in-kind support for the laboratory.

The LTR program used three research mechanisms: (1) multi-year projects, (2) quick-response projects, and (3) major industry partnerships. Each of the three mechanisms is described here. The multi-year project mechanism was the primary vehicle used.

Multi-Year Projects: Multi-year projects were cost-shared projects between private industry and multi-program laboratories. Awards ranged from $100,000 to $250,000 per year for 3 years, and the projects were implemented through Cooperative Research and Development Agreements (CRADAs). Companies did not receive Federal funds to participate and were required to contribute resources (in-kind resources and funds to the laboratories) that were equal to, but frequently exceeded, those provided by the DOE.

The criteria for selecting proposals were:

- Scientific/technical quality
- Qualifications of principal investigator (PI) and facilities
- Work plan
- Commercial/technological potential
- Industry partner participation (Payne and Kniel 2000)

The industry partner participation component of proposals required at least one national laboratory partner and one (or more) industry partners that would match DOE funding either through in-kind support, funds-in support, or a combination of the two. The strength of the partnership was further evaluated based on the extent of industry partner participation, and their prior track record with other LTR projects. The DOE sent each proposal to three technically knowledgeable external peer reviewers who had been screened for potential conflicts of interest. In the last year of the program, 2004, the DOE funded 57 projects.

Quick-Response Projects: The quick-response mechanism (known as "rapid access projects" beginning in 1998) was a technical assistance program. It primarily supported projects for small businesses to rapidly address challenging technical problems by tapping into the expertise of laboratory researchers. Through CRADAs, these projects provided targeted research support through personnel exchanges, technical assistance consultations to small businesses, and small collaborative projects. The project selection was based on merit review of the project's scientific and technical quality, commercial potential and potential contribution to DOE mission. Project lengths varied from a few days to one year, with funding of $3,000 to $100,000 per project. Total funding for quick-response projects ranged from $0.9 to $1.4 million for FYs 1996, 1997, and 1998, the years for which data are available (DOE 1996, 1997, 1998).

Major Industry Partnerships: Major industry partnerships were designed to pair teams of DOE national laboratory scientists and engineers with the industrial sector to research pre-competitive technologies for the mutual benefit of both the private and public sectors. Projects also tackled generic problems facing industry (DOE 1997).

From the point of view of industry participants, all three LTR mechanisms were considered to be successful (see the sidebar for an example). In a 1998 survey of the LTR program administered by Oak Ridge National Laboratory, 97% of respondents stated they would like to partner with DOE Office of Science laboratories again, and 91% of respondents asserted that they had benefited from the partnership with the laboratories (Payne and Kniel 2000).

Over time, the program eventually lost support as Congress became increasingly divided over the role of public-private partnerships in technology commercialization. LTR program funding peaked at $45 million in FY 1995 and subsequently declined to $3 million in fiscal year (FY) 2002.[3] A significant fraction of the $45 million was used for the American Textiles Partnership (AMTEX), which lasted about 3 years (Yarris 1993). After 1996, the LTR program was not a line item program, but instead was part of the High Performance Computing program budget. The LTR did not fund new projects beginning around 2000, but small amounts of funds were provided to complete projects until the program ended in FY 2004.

LTR Program Helps Company Avoid Production Shutdown

Clover Club, a bottling company in Chicago, Illinois, discovered bacterial contamination in its production process but could not identify the source of the contamination. Clover Club's president, Joseph Troy, contacted Argonne National Laboratory staff who analyzed sampling data and cleaning procedures. DOE laboratory researchers identified the contamination source and recommended improved cleaning procedures. According to Troy:

> Our plant was in danger of production shutdown because of microbial contamination in our bottling process, and we couldn't find the source. Argonne identified the source and assessed our cleaning process, allowing us to work with a private consultant to eliminate the problem and production was resumed. For us, this technical assistance was essential in keeping our employees working.

Argonne's Technical Services Program was funded by the DOE's Office of Science LTR program.

Source: Argonne National Laboratory (Undated).

[3] During the same timeframe, the DOE Office of Defense Programs (DP), now the National Nuclear Security Administration (NNSA), funded a similar program called Technology Partnerships Program (TPP). TPP had a budget of $216 million in FY 1995. TPP funding was typically reserved for DP laboratories and LTR funding was typically reserved for Office of Science laboratories.

2. DOE Office of Energy Efficiency and Renewable Energy Technology Commercialization Fund

Congress initiated another DOE-wide technology maturation program through the Energy Policy Act of 2005 (Public Law 109-58). This act specified that 0.9% of funds allocated for DOE applied energy research, development, and demonstration shall be used to develop technologies for commercialization.

> The Secretary shall establish an Energy Technology Commercialization Fund, using 0.9 percent of the amount made available to the Department for applied energy research, development, demonstration, and commercial application for each fiscal year, to be used to provide matching funds with private partners to promote promising energy technologies for commercial purposes (42 U.S.C. § 16391(e)).

The DOE Office of Energy Efficiency and Renewable Energy (EERE) responded by organizing the Technology Commercialization Fund (TCF) in 2007, which lasted until 2008. The TCF was designed to complement angel or venture capital investment in early-stage corporate product development. The fund totaled almost $14.3 million for 2 years in FY 2007 and 2008. According to EERE, TCF brought together DOE's national laboratories and industry to identify promising technologies facing the "Commercialization Valley of Death" (DOE EERE 2012).

The TCF selection criteria for proposals required that projects focus on prototype development, demonstration, and deployment, rather than further scientific research. Proposals were evaluated on:

- Potential market opportunity
- Likelihood of commercial success
- Management team
- Alignment with DOE priorities
- Private sector partners

TCF projects were also required to have a 50/50 cost-share from industry in order to show the viable path to commercialization as well as demonstrate market interest in that technology.

Three laboratories, ORNL, National Renewable Energy Laboratory (NREL), and Sandia National Laboratories (SNL) obtained TCF awards the first year. EERE initially allocated TCF funding based on the proportion of program funding received by each laboratory. The next year EERE also considered how aggressive the commercialization program was at each laboratory and provided TCF funds to ORNL, NREL, PNNL, Lawrence Livermore National Laboratory (LLNL), and SNL (see Table 1).

The DOE instructed laboratories to give awards up to $250,000; however, exceptional projects could receive up to $500,000. Over 50 companies received technology commercialization funds through this program. Examples of outcomes from TCF projects selected and funded by SNL are provided in Table 2.

Table 1. Technology Commercialization Funds Received by DOE Laboratories

Laboratory	Abbreviation	TCF Funds (2007–2008)
National Renewable Energy Laboratory	NREL	$4.0M
Oak Ridge National Laboratory	ORNL	$4.0M
Lawrence Berkeley National Laboratory	LBNL	$1.5M
Pacific Northwest National Laboratory	PNNL	$1.5M
Sandia National Laboratories	SNL	$1.4M
Los Alamos National Laboratory	LANL	$0.7M
Argonne National Laboratory	ANL	$0.7M
Lawrence Livermore National Laboratory	LLNL	$0.5M

Table 2. Outcomes of Technology Commercialization Projects at Sandia National Laboratories

Partner	Project	Outcomes
Automotive Fuel Cell Corporation	Deployment of SNL's fuel cell membrane	Project goals met. SNL maintains a good relationship with Automotive Fuel Cell Corporation, including work under CRADAs and a joint proposal submitted to the DOE Hydrogen Program.
Accelergy Corporation	Designer catalysts for next generation fuel synthesis	U.S. Patent 7.951.747 was awarded; however, Accelergy postponed commercial activities in 2009 due to an ailing economic environment. Ecocat Corporation, a new partner, will focus on establishing CRADA for commercialization.
H2Scan	Hydrogen sensor commercialization for hydrogen fuel cell vehicles	H2Scan has commercialized the SNL technology for several challenging industrial applications, including continuous operation in petrochemical refineries, hydrogen production, and chloralkali manufacturing.
Advent Solar/Applied Materials	Advent solar emitter wrap-through cell with monolithic module assembly technology	The research program was a success. SNL helped Advent Solar solve a subset of its process/manufacturing issues. Applied Materials, who purchased Advent Solar, is licensing SNL technologies, indicating the value of IP produced.
Solar Infra	ACE System – Fully Integrated Plug-Play AC Solar Energy System	Successfully developed the ACE system, which is a highly reliable photovoltaic alternating-current system that can operate in extreme sun, wind, and snow conditions. Negotiations between Solar Infra and Enphase are stalled due to IP issues.

Source: Email communication with Mary Monson, Manager, Partnerships Development & Business Intelligence, Sandia National Laboratories, January 28, 2013.

The TCF was funded for 2 years. Some criticized the program because project selections were made by headquarters personnel rather than by program managers or laboratory personnel. Others viewed TCF as taking money away from certain laboratories and giving it to others.

C. DOE Laboratory Technology Maturation Programs

DOE laboratory technology maturation programs provide small amounts of funding to move early-stage technologies to proof-of-concept or prototype stage to attract potential licensees or investors. Awards are given to achieve a specific milestone or set of milestones. The laboratory representatives stated that the small amount of funds dedicated to technology maturation has been successful in encouraging companies to license technologies from the laboratories. Appendix C provides details on a selection of technology maturation programs at several DOE laboratories.

STPI researchers spoke with representatives from

- Seven DOE laboratories with technology maturation programs: ANL, BNL, LBNL, LLNL, LANL, ORNL, and PNNL;
- Two DOE laboratories with informal programs: Ames Laboratory and NREL; and
- Four DOE laboratories that do not have programs: Thomas Jefferson National Accelerator Facility, National Energy Technology Laboratory, SLAC National Accelerator Laboratory, and SNL.

1. History of Programs

Many of the DOE laboratory technology maturation programs started between 5 and 10 years ago. For example, LANL started its program in 2003. Between 2003 and 2011, LANL invested $2.6 million in 61 projects, with an average award size of $50,000 (Mott 2011). At some laboratories, these programs originated about 4 to 5 years ago in response to a shrinking economy and disappearing venture capital funds (PricewaterhouseCoopers 2013). Other programs, however, started more recently due to increased interest in bolstering the economy by accelerating technology transfer from Federal laboratories, ultimately encouraging entrepreneurship and the creation of new startup companies. At present, LBNL and LLNL are in the third year of their programs. Another laboratory established its program after a successful experience with a TCF-funded project. Although BNL was authorized to initiate a program about 5 years ago, the laboratory did not begin to focus on maturation until about 2 years ago.

2. Types of Projects Funded

Technology maturation programs are used to advance technology to the point where a company is willing to develop it further, with the ultimate goal to commercialize the technology. This can be an iterative process, sometimes requiring a few rounds of technology maturation funding. Examples of activities include conducting research targeted to commercial needs, developing prototypes, testing the technology, gathering additional data, scale-up, and demonstration.

3. Criteria and Selection Process

Projects are approved following two broad approaches. The first is through a formal proposal submission. LLNL works with external entrepreneurs and angel investors to choose technologies to receive maturation funds. At LANL, researchers submit two-page proposals that are reviewed by the Technology Management and Development Office, with a focus on potential return on investment through a license or CRADA. At BNL, the Office of Strategic Management issues a call for proposals and the awards are approved by a panel that certifies the proposal is for maturation and not basic science research.

The second approach allows for more informal submission of ideas. At LBNL, division directors select the projects to receive maturation funds. At ORNL, NREL, and PNNL, researchers submit proposals or ideas when ready and they are either approved or rejected by the technology transfer or commercialization offices.

In general, projects are more likely to be funded if the proposal provides evidence of industry interest in the technology. If there is a call for proposals, specific criteria must be met before projects are reviewed. Additional criteria are used to evaluate technological and commercial viability and the potential impact of innovation. Table 3 is a summary of the methods of selection used at various laboratories.

Table 3. DOE Laboratory Review/Selection of Projects for Technology Maturation Funding

Laboratory	Method of Review to Select Technology Maturation Proposals
Argonne National Laboratory	Vetted by internal and external committees.
Brookhaven National Laboratory	Licensing associates work with PIs and talk to companies to assess market interest
Lawrence Livermore National Laboratory	Entrepreneurs and angel investors identify potential TMF projects
Los Alamos National Laboratory	Technology Management and Development Office
Oakridge National Laboratory	Technology Transfer Manager and Associate Laboratory Director

4. Size, Quantity, and Length of Projects

As Table 4 indicates, laboratories fund about 2 to 15 projects per year,[4] and individual awards typically range from $50,000 to $100,000. ANL, BNL and PNNL also fund large projects up to $250,000 and $400,000 if they involve expensive equipment, scale-up, or demonstration.

Table 4. Size and Numbers of Technology Maturation Projects Funded per Year

Laboratory	Annual Funding (2012)	Funding Range	Number of Projects (2012)
Argonne National Laboratory	$600K*	$100–150K, up to $250K	6
Brookhaven National Laboratory	$250K*	$30-90K, up to $400K	2−5 (out of ~10)
Los Alamos National Laboratory	$1M	$50–100K	10+
Lawrence Livermore National Laboratory	$600K	$50–100K	12
Lawrence Berkeley National Laboratory	$500K	$50K	8 (out of 48 applications)
National Renewable Energy Laboratory	$150K	$25–50K, up to $100K	3−6
Oakridge National Laboratory	$500K	—	Funds about ½ of viable projects
Pacific Northwest National Laboratory	$600K−$1M*	$50K, up to $400K	70

Note: Figures for 2012 are used as examples. Some laboratories noted that their royalty and licensing income was lower in 2012 than previous years.

* Estimate.

In all cases, the demand for technology transfer funds exceeded supply. Many of the laboratories' personnel said that they are only able to fund about half the projects that could benefit from technology maturation funding.

5. Amount and Source of Funding

The total size of DOE laboratory-managed maturation funds were usually $200,000 to $600,000 per year. Most laboratories use some portion of revenue generated from royalties, generally 25% to 35%, to support technology maturation or innovation funds. Some laboratories augment the fund through the use of a portion of the fees provided to the laboratory contractor by the DOE. Additional support comes from state governments,

[4] PNNL funds about 70 projects a year.

which provide resources for technology maturation through proof-of-concept funds or technology acceleration funds.

One laboratory created a technology maturation program within the Laboratory Directed Research and Development (LDRD) program.[5] The selected projects had a clear potential for economic impact. The goal was to enable laboratory researchers to understand potential commercial outcomes and encourage interactions with companies. However, LDRD is scrutinized both internally and externally, and the belief that LDRD funds should be used solely for research and not maturation can pose a challenge.

6. Tracking Success

DOE laboratories monitor these projects using a variety of short- to mid-term metrics. These include the number of licenses, license revenue, and additional funding such as Small Business Innovation Research (SBIR)[6] or venture capital money associated with the technology maturation project. They also track success using longer term metrics, such as the number of start-ups, successful entry of product to market, and creation of jobs. One laboratory representative noted that the goal is not always the release of a commercial product, but industrial use of a process. Companies often license processes and use them internally, and this is also considered a successful result. Tracking success over the life cycle of the technology is challenging since the development timeline may take many years and require multiple efforts to result in a commercial product with widespread impact. Table 5 provides example metrics. The sidebar below provides one example of a success story from a DOE laboratory technology maturation fund; additional success stories are described in Appendix C.

A DOE Laboratory Success Story—Black Silicon

The National Renewable Energy Laboratory (NREL) “black silicon” nanocatalytic wet-chemical etch technique is a one-step process creating high-efficiency solar cells based on an innovative anti-reflection approach that significantly reduces manufacturing costs. NREL estimates that its method can reduce processing costs by 4% to 8%, making black silicon competitive. This technology was selected into NREL’s Privately Funded Technology Transfer program, and was successfully transferred through a license agreement in 6 months. The wet-chemical etch technique was a winner of *R&D Magazine*’s R&D 100 Award as one of the top technology products of 2010.

Source: NREL (2011).

---

5 “LDRD serves as a proving ground for advanced R&D concepts that are often subsequently pursued by DOE programs and, at the same time, helps the Government identify more creative approaches to fulfilling future mission needs.” Go to the following website for more information: http://science.energy.gov/lpe/laboratoryoratory-directed-research-and-development/doe-philosophy-on-ldrd/.

6 The SBIR program requires Federal agencies with an extramural research budget in excess of $100 million to reserve a small percentage of their funding for contracts or grants to small businesses.

Table 5. Examples of Metrics for Tracking Success of Technology Maturation Funding over the Technology's Life Cycle

	Type of Metric
Short-term	Acceleration of R&D: • Constructing a prototype • Measuring the efficacy/efficiency of a prototype • Analyzing the products of a key experiment • Comparing the product with existing products • Collecting performance data for a new material, process, or apparatus
Mid-term	Patents, publications, presentations Funding from state Additional DOE program funding New agreements/collaborations: • CRADAs • Licenses
Long-term	Economic growth: • Market entry of new products and process • Startups, growth of existing companies • Creation of jobs
Impacts	Uses of the technologies resulting in: • Lives saved • Increased use of renewable energies • Spillovers to other sectors

D. University Technology Maturation Programs

University technology maturation programs are also designed to move technology further toward a commercial application and license. As one interviewee explained, the goal of their maturation funding program is "to push technology closer to licensing or creating a start-up." STPI researchers spoke with representatives from the seven university transfer offices listed below:

- Cornell University, Center for Advanced Technology, Biotechnology Center
- Harvard University, Biomedical Fund Accelerator
- Princeton University, Intellectual Property Accelerator Fund
- University of Michigan, Technology Transfer Office
- Massachusetts Institute of Technology (MIT), Deshpande Center
- Johns Hopkins University, Maryland Innovation Initiative
- University of Iowa, Iowa State University Research Foundation

The university technology maturation funds chosen for study represent a mix of characteristics. These include university types (three public and four private), source of funds (state, philanthropic, endowment, university funded, or multiple sources), discipline (five broad and two in biotechnology), and known interactions or geographic proximity to labs (three laboratories). Given the small number interviewed, this is obviously not a representative list. Instead, the discussions with these universities provided interesting comparisons and ideas for DOE laboratory technology maturation programs.

1. History of Programs

The seven universities described in this report, have had maturation funding for varying lengths of time. Some universities have had organized maturation funds for the last 10 or 20 years, while other programs have been created more recently, several in the last 5 years and two in last 2 years. University staff indicated they experienced the same sharp decline in venture capital funds during the economic slowdown. Cornell University had a maturation fund as early as the 1980s. This fund was developed in the wave of support following the Patent and Trademark Act Amendments of 1980 (P.L. 96-517, also known as the Bayh-Dole Act), but was ultimately discontinued and has recently been replaced by a new program.

University staff described a range of motivations for initiating maturation programs, including a perceived need to move technologies off the shelf and a push to stimulate economic growth in their regions. One university staff member explained that the original impetus for creating a maturation fund came from the state government, which recognized that there was a large gap between "university discovery and company adoption," particularly in the life sciences, prompting the creation of a maturation fund for biotechnology. The MIT Deshpande Center was established for the explicit purpose of fostering an entrepreneurial environment in the region surrounding the university.

2. Types of Projects Funded

University technology maturation programs fund projects that require a proof of principal, additional development, validation studies, or some other assistance to bridge the valley of death between research and the market. Projects are also designed to generate and enhance intellectual property positions to make research products more attractive for licensing or as the basis of a start-up company. Some programs are oriented towards a specific field. For example, the Harvard Biomedical Fund Accelerator (Harvard University 2013) and the Cornell Biotechnology Center focus on life science projects.

3. Criteria and Selection Process

University maturation funds usually distribute funds either through an annual request for proposals or, more commonly, an open call from the technology transfer office on campus. The selection criteria of all of these programs center on a combination of technical validity and commercial potential. According to the managers of some funds, selection is dependent on the perception of whether "a grant of around $250,000 will be impactful" to the commercial potential of a project, while according to others, selection is more broadly targeted to any projects that need "to increase the amount of data behind new science" and is not tied to a particular development stage.

Although most funds do not require that researchers with maturation proposals find co-sponsors, several noted that they are looking to see that PIs are open to speaking with potential commercial partners and that they are thinking about market viability. Others look to address specific market issues, and require the identification of a willing commercial sponsor as part of a proposal.

Evaluation processes vary by program. For example, the Princeton University Intellectual Property Accelerator Fund involves review by a committee of university researchers, technology transfer office staff, and one or two private venture capitalists. In general, most programs seemed to involve representatives from the university research community to assess technical validity and commercial investors, entrepreneurs, or technology transfer representatives to assess the market viability.

4. Size, Quantity, and Length of Projects

Projects funded through university maturation programs that we talked to range from $5,000 for answering targeted market questions up to $1 million dollars for multi-year research efforts. The majority of these programs funded grants in the range of $25,000 to $100,000. The MIT Deshpande Center has developed a bifurcated funding program, supporting early-stage "ignition" grants with $50,000 to $100,000 for a year and more advanced "innovation" proposals with up to $250,000 for the same time period. Although the majority of university projects were funded for one year, some grants provided funding for up to 2 years. Only one program noted that it was beginning to offer multi-year projects that could reach up to a million dollars to tackle more complex issues.

The number of projects funded by these university maturation funds varied depending on the size of the fund, the number of proposals being submitted, and the targets of the program. The majority of these programs can fund between 6 to 12 projects on an annual basis. One program with a particularly limited funding base supported 2 to 4 projects a year, while another program that gave out smaller funding amounts for specific market questions provided almost 20 awards a year. University program representatives noted that they could support 3 to 12 additional projects if funding constraints were not a factor.

5. Amount and Source of Funding

Total university maturation funds (based on the ones in this study) range in size from $200,000 to $2 million per year, with most universities falling in the $500,000 to $1 million range. There were a variety of sources given for this funding. At least two were based on philanthropic donations, one from graduates of the institution and one from a single individual. Several others were supported by funding from the state government for the purpose of fostering economic development in the university community and geographic region. A few of the funds were also supported by internal university or endowment funds. Only one included funding reinvested from royalties from technology licenses. For example, the Maryland Innovation Initiative is a multi-university collaborative fund supported by the state government (Lambert 2012). This program has reached a size of $5 million, based on funding from six University of Maryland schools and state funds.

6. Tracking Success

University technology maturation fund managers monitor the success of their maturation investments using a variety of metrics. For most of the funds, these metrics relate to each project's ability to reach the marketplace. In particular, several interviewees referenced monitoring the number of licenses and start-ups as indicators of maturation success. Others considered the outcomes of the licensed technologies or the resulting start-ups to be an important reflection of the success of the maturation investment.

A few of the program representatives mentioned that follow-up research funding was a good proxy for success; if a maturation project is able to attract commercial research funds, then it is viewed as an effective maturation investment. This is especially helpful in cases where technologies were not yet at the patent or license stage. However, this metric can be misleading because a second investment still does not mean the technology will reach the market.

At least one fund manager explained that his office did not collect specific metrics, but he engaged with project leaders individually to learn about the commercial outcomes of their investments. Almost all of our university interviewees also cautioned that metrics were not useful in the short term since most technologies take from 2 to 30 years or more after maturation funding to become a commercial product. The sidebar below provides an example of a success story from a university technology maturation fund; additional success stories are described in Appendix D.

A University Success Story—Technology Maturation Leads to License

A biological discovery by two Harvard University professors identified several proteins that they believed had the potential to slow cell degradation associated with cognitive degeneration. The researchers approached the commercial sector with their discovery but were unable to find an investor. Using a relatively modest maturation grant of $350,000 (supplemented by additional funds from an angel investor) the researchers were able to develop potential compounds and begin animal testing. After a year of maturation research, they returned to industry and were able to license the technology to a local biotechnology company. This demonstrated the success of maturation because it showed how a fairly modest investment was able to take something that was previously un-licensable and make it more interesting to companies.

E. Improving Technology Maturation Funding

1. Support for Technology Maturation Funding across the DOE

While many DOE laboratories have initiated their own technology maturation programs, supporting technology maturation across the DOE, particularly within basic science programs, is still a controversial topic. Arguments from interviewees against technology maturation included the assertion that the products of DOE basic research laboratories, such as those found in the Office of Science, are too far removed from the market to justify funding their advancement. Others argued that DOE's Office of Science mission does not include technology maturation. However, as a DOE official noted, it would not be possible to implement DOE's overall mission "to ensure America's security and prosperity" unless laboratory technologies ultimately reach the market. Additional interviewee quotes supporting technology maturation for basic science programs include:

- "Without maturation, basic science will not be able to do things in the real world. The VC [venture capitalist] and private sector communities have a low risk tolerance, so it is crucial to get fundamental, game-changing technology to a stage where they will attract larger funds."
- "If they want to put their money where their mouths are and commercialize technology, and place importance on moving technologies from the bench, etc., then the Office of Science needs to learn more from EERE and invest more. Not debatable."
- "The laboratory is often exploring very basic science that is explored without a commercial purpose in mind…if you're not willing to connect the dots; the risk is that the investment in science will remain just that. To retain fullest use, there is a need to spend those last dollars to align science with the needs of industry and reduce the risk."

The GAO report highlighted the "lack of funding to develop and demonstrate promising technologies in order to attract partners willing to commercialize them," as one of three primary challenges for DOE technology transfer (GAO 2009). The report made no distinction between DOE basic research programs and applied research programs. In addition, a report stemming from a forum on Federal technology transfer sponsored by the President's Council of Advisors on Science and Technology stated that the steps following invention, including prototyping and product development, are critical to the ultimate success of Federal-to-private technology transfer (Wang et al. 2003).

Understanding the Link between Basic Research and the Application of the Research Is Important to Both Activities

Basic science research, though fundamental by definition and often highly theoretical, contributes a unique knowledge set to the innovation ecosystem. By its nature, basic science often has unforeseen applications and may be critical to further development or augmentation of mature technologies already in use. Donald Stokes created Louis Pasteur's Quadrant to highlight the distinction between use-inspired basic research and pure basic research. Use-inspired basic research bridges the gap between basic and applied research and seeks to increase fundamental understanding of scientific problems for the eventual benefit of society (see Figure 1). Stokes (1997) notes that Pasteur was at the forefront of the microbiology revolution, which highlighted the relationship between basic research and technological change. Thus, even pure basic research conducted at DOE laboratories may be linked to applications through use-inspired research.

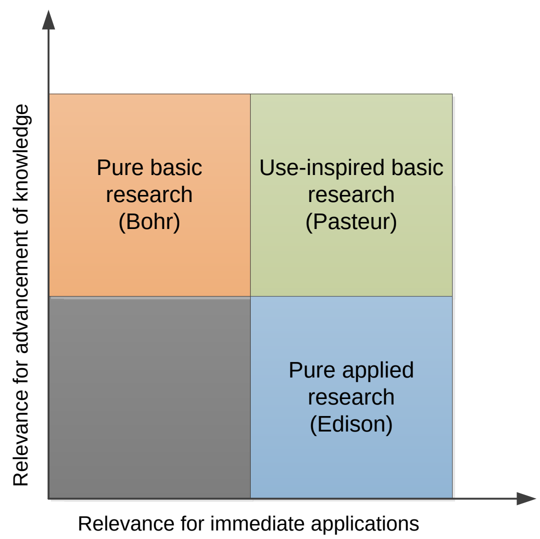

Figure 1. Pasteur's Quadrant

Other government programs exist for the same purpose. For example, according to the National Science Foundation (NSF) website, the goal of the NSF Innovation Corps (I-Corps) is "to foster entrepreneurship that will lead to the commercialization of technology that has been supported previously by NSF-funded research."[7] However, funds in other Federal programs, such as SBIR, are insufficient to develop all available technologies that could be matured. Technology maturation funds help laboratories manage an active technology pipeline.

In that vein, interviewees outlined how the DOE and laboratory programs (including the LTR and TCF) were beneficial to the DOE and the nation as a whole. The core benefit, according to the technology transfer representatives, is that it increases the

[7] About I-Corps, http://www.nsf.gov/news/special_reports/i-corps/about.jsp.

number of technologies that are brought to market. These programs provide the incentives for DOE laboratories to actively partner with industry, which facilitates interaction with industry experts and helps researchers and staff think about potential uses of their technologies. It also promotes understanding of commercial impact. Interviewees noted that DOE laboratory researchers conduct world-class science. Programs that support maturation of research, including basic research, offer a unique opportunity for these researchers to solve real-world problems. According to one interviewee, even if a maturation investment was unsuccessful in bringing a technology to market, it still benefits the DOE as it provides greater understanding of market need and the direction of future investment.

2. Design Options for a DOE Technology Accelerator Fund

Options for a DOE-wide technology maturation program are based on interviews with stakeholders, past participants, and university technology transfer offices. A DOE Technology Accelerator fund could augment existing DOE laboratory maturation funds and provide technology maturation entirely for laboratories without funds. DOE could also help laboratories identify other sources of technology maturation funds, such as state funding.

The fund could help mature the technologies to the point that companies are interested in developing them further for commercialization. To be most effective, the fund could be open to all science and technology topics in DOE mission areas. The fund could provide support for research targeted to commercial needs, prototype or proof-of-concept development, collection of additional data, scale-up, or demonstration.

Other features of a technology maturation program funded by the DOE could include:

- *A program name to convey excitement and to market the program inside and outside the DOE*. Some technology maturation program names create excitement about the process. For example, existing program names include Ignition Fund, Innovation Grant, Fund Accelerator, Intellectual Property Accelerator Fund, and Translational Research Program. Interviewees recommended avoiding terms such as “commercialization” and “maturation” because they emphasized industry benefit, which is not necessarily the focus of technology development. Instead, “accelerator” was proposed as an appropriate descriptor of the fund.
- *Program or laboratory management*. A DOE-wide program could be managed at the program level or at the laboratory level. In either case, the fund must have support from the DOE, the laboratories, and program directors. One approach could be a DOE-wide program that is deployed to supplement current maturation programs at each laboratory; with requirements to meet minimum DOE-specified criteria but allowing each laboratory to tailor it to their needs.

- *Clearly defined criteria for a competitive selection process*. A good starting point would be the criteria used by the LTR Program, TCF, and current laboratory technology maturation programs. For example, the LTR required: (1) scientific and technical quality, (2) qualifications of principal investigator and facilities, (3) maturation plan and selected milestones, (4) commercial and technological potential, (5) industry partner participation (with cost-share) or identification of potential industry partners, and (6) possible interest of the researcher to assist a start-up or licensee. The competitive selection process would ideally involve representatives from the research community to assess technical validity and commercial investors, entrepreneurs, or technology transfer representatives to assess market viability.
- *Modest funding requirements*. The funding requirements are modest, ranging from $250,000 up to $1 million per year per laboratory or $4.25 million to $17 million across the DOE per year. This baseline is derived from what the laboratories are currently spending. The upper bound reflects the estimate based on the number of viable projects that are currently not being funded. If the program is successful in creating an entrepreneurial culture at the laboratory, then funding may need to increase as scientists propose more projects for maturation. In addition, the DOE could help laboratories identify other sources of technology maturation funds, such as state or venture capital funding.
- *Well-defined metrics to track and publicize successes*. Establishing a common set of metrics to track success over the life cycle of projects would allow the DOE to monitor the effectiveness of the program. It is important to note that any performance goals should measure technology maturation to commercialization using short to long-term metrics because the time after maturation funding to commercial product can be from 2 to more than 30 years.

F. Conclusion

This report discussed the history and implementation of DOE and national laboratory technology maturation programs. In addition, we examine university technology maturation programs. Both the Federal and university programs provide ideas for creating a DOE-wide program as well as methods for DOE laboratories wishing to enhance their existing programs.

DOE technology maturation programs have evolved over the last 20 years, starting first with DOE-funded programs and recently emerging at the laboratory level. These programs provide necessary additional development to move early-stage technologies to a point where the private sector can make the investments to turn them into commercially viable products. They can encourage laboratory researchers to think about the market potential early in the development cycle, lead to income for the laboratory, and spur economic development. Because the timelines for these developments can be long (ranging from 2 to 30 years), providing a steady stream of technology maturation funding will help to ensure a flow of inventions from the laboratory to innovations in the marketplace.

Appendix A.
Individuals Interviewed

Department of Energy (DOE)

Sam Barish
Office of Science, DOE 3D Topologies Team Lead (Former head of LTR)

Drew Bond
Battelle, Vice President of Public Policy (Former DOE EERE)

Patricia Dehmer
Office of Science, Deputy Director for Science Programs

Karina Edmonds
Department of Energy, Technology Transfer Coordinator

Wendolyn Holland
Holland Consulting LLC, Independent Consultant (Former DOE EERE)

DOE National Laboratories

Office of Science Laboratories

Debra Covey
Ames Laboratory, Associate Director for Sponsored Research Administration

Deborah Clayton
Argonne National Laboratory, Technology Development and Commercialization

Walter Copan
Brookhaven National Laboratory, Managing Director, Office of Technology Commercialization and Partnerships

Jay Patrick Looney
Brookhaven National Laboratory, Chair of Sustainable Energy Technologies Department

Gerry Stokes
Brookhaven National Laboratory, Associate Laboratory Director for Global and Regional Solutions

Cheryl Fragiadakis
Lawrence Berkeley National Laboratory, Department Head of Technology Transfer and Intellectual Property Management

Michael Joseph Paulus
Oak Ridge National Laboratory, Director of Technology Transfer

Vincent Branton
Pacific Northwest National Laboratory, Legal Department

Marty Conger
Pacific Northwest National Laboratory, Chief Finance Officer and Associate Laboratory Director - Business Systems

Bruce Simanton
Pacific Northwest National Laboratory, Sales Management

Janet Tulk
Stanford Linear Accelerator, National Accelerator Laboratory, Contracts Manager

Joseph Scarcello
Jefferson National Laboratory, Chief Financial Officer & Manager Business Operations

Roy Whitney
Jefferson National Laboratory, Chief Technology Officer

Office of Energy Efficiency and Renewable Energy Laboratories

William Farris
National Renewable Energy Laboratory, Associate Laboratory Director, Innovation, Partnering, and Outreach

Matt Ringer

National Renewable Energy Laboratory, Commercialization Program Manager, EERE Energy Innovation Portal

National Nuclear Security Administration Laboratories

Erik Jon Stenehjem
Lawrence Livermore National Laboratory, Director of the Industrial Partnerships Office

Roger Werne
Lawrence Livermore National Laboratory, Director

John Mott
Los Alamos National Laboratory, Technology Transfer Division

Mary Monson
Sandia National Laboratories, Business Development Manager

Office of Fossil Energy, Office of Energy Efficiency and Renewable Energy, and Office of Electricity Delivery and Energy Reliability Laboratory

Jessica Sosenko
National Energy Technology Laboratory, Technology Transfer Analyst

University Technology Transfer Offices

Amy Francetic
Clean Energy Trust, Executive Director

Alan Paau
Cornell University, Executive Director and Vice Provost for Technology Transfer & Economic Development

Curtis Keith
Harvard University, Associate Director of Business Development

Isaac Kohlberg
Harvard University, Senior Associate Provost and Chief Technology Development Officer

Wesley Blakeslee
Johns Hopkins University, Executive Director of Technology Transfer

Lita Nelsen
MIT, Director of Technology Licensing

John Ritter
Princeton University, Director of Office of Technology Licensing

Zev Sunleaf
University of Iowa Research Foundation, Executive Director

Ken Nisbet
University of Michigan, Executive Director of Technology Transfer

Appendix B.
Discussion Guide

Project Overview

The White House Office of Science and Technology Policy and the Department of Energy asked our organization, the IDA Science and Technology Policy Institute, to write a short white paper about technology maturation funds. This white paper will discuss the history of technology maturation funds at the Department of Energy, benefits to such funds, and the features of existing funds. This interview will relate to the design of your technology maturation fund and its benefits.

Consent Statement

Your participation is completely voluntary, and our conversation will be audio-recorded, but if you'd like to tell us something that is off the record, feel free to do so. We will stop recording and writing until you tell us that we can start again. We may quote you or attribute statements to you or your project. If we quote you, we will ask you to review these quotations.

Your Background

- What do you do in your day-to-day job?
  - How are you involved with your technology maturation fund?

Technology Maturation Fund History

- When and how did your technology maturation fund begin?
  - Whose idea was it?
  - What was necessary to start the fund?
    - Did it have a champion?
    - Did you have surplus funds?
  - Why did the organization decide to devote resources to technology maturation?
- What types of technologies do you fund?
  - Certain sectors or fields?

    - Specific development or readiness levels?

Technology Maturation Fund Success and Metrics

- What technologies are the fund's greatest successes?
- Aside from these technology development successes, are there other benefits to the fund?
- How do you measure the success of your technology maturation fund?
    - Do you use metrics to measure this success?

Technology Maturation Fund Features

- How much money do you spend funding technologies each year?
    - Where does the money come from?
        - If the money comes from several places, does it get allocated back to technologies from those places?
- How do you decide which technologies to fund?
    - Is it a competitive process?
        - Who is in charge of picking the technologies to fund?
- How long do you fund each technology?
    - Do technologies get funded for a set period of time?

Miscellaneous Questions

- Do you know of any other organizations that have successful technology maturation funds?
    - If so, what are their names?
    - What is unique about their funds?
    - Why do you consider them successful?
- Do you recommend that we talk to anyone else about their technology maturation fund?
    - If so, why?

Thank You

We greatly appreciate your participation in these interviews. Thank you!

Appendix C.
Descriptions of Technology Maturation Funds at Selected DOE Laboratories

Ames Laboratory

- Ames does not have a formal technology maturation fund, but in the past has used royalty income to take technology to the last oasis within valley of death. Also, the Iowa State University Research Foundation, Inc. (ISURF) has a small technology maturation fund available to some Ames technologies.
- **Project selection:**
  - The principal investigator (PI) comes to talk to the technology transfer office and then the PI writes up a proposal for a certain amount of funding. The laboratory director makes funding decisions.
  - Selection depends on what the goal is and that the project is furthering the technology development.
  - Also, ensure the technology is fulfilling the DOE's mission.
- **Source of funding:** Royalties; have had sufficient royalties for the last 7 years.
- **Annual funding and number of projects:** $25,000– $100,000 per project. Ames royalties allow for one technology maturation project per year, and the university might do one or two.

Argonne National Laboratory Technology Maturation Program

- **Start year**: 2011
- **Project selection**: Project leaders are invited to submit proposals through an internal solicitation or request for proposals. The proposals are vetted by a committee of internal and external members (including venture capitalists) for commercialization efficacy and probability that the narrowly characterized issue to be addressed is the issue constraining commercial success (i.e., licensing or continued sponsorship toward commercialization).
- **Source of funding**: Royalty income

- **Annual funding and number of projects**: Funds projects in the $100,000 to $150,000 range, on average, up to $250,000. Recently six projects were funded, five of which led to licensing or funded follow-up work.
- **How many viable projects are not funded due to lack of funding?** None using the existing criteria, which are quite strict.
- **Challenges**: Estimating the probability of commercial success for relatively early-stage technologies.
- **Metrics**: The primary metric is whether the project enables the technology to move forward to a more advanced development phase under external sponsorship or creates evidence of efficacy (risk reduction) leading ultimately to a license. A secondary metric is return on investment—does the investment in the technology maturation yield an equal or greater investment by others to commercialize or use the technology?
- **Success stories**:
  - Developed a new application for an existing bio-assay ("lab-on-a-chip") for bovine mastitis, providing diagnostic capability on site with the herd. The rapid turnaround of results enables immediate decisions resulting in substantial economic savings and risk reduction. A team came together to compete in the University of Chicago New Venture Challenge, tying for fourth place. A business plan has been drafted for a startup company and the team is now receiving guidance from the Chicago Innovation Mentors group, in which experienced entrepreneurs "adopt" a startup company and guide it through the early phases of formation and growth. http://www.anl.gov/articles/biochips-investigate-cattle-disease-win-entrepreneurial-challenge.
  - Developed a technique that employs atomic layer deposition to deposit thin, electrically conducting films on the inside surfaces of porous glass at a fraction of the traditional cost. This capability has applications in high-energy physics, medical imaging, and homeland security. The matured technology received a 2012 R&D 100 award from *R&D Magazine* for the "Large Area Microchannel Plate" (http://www.anl.gov/articles/argonne-wins-four-rd-100-awards and http://web.anl.gov/techtransfer/Available_Technologies/Sensor_Technology/microchannel_plate_detector.html).
- **Other**: An early-stage proof-of-concept program focuses on conceptual ideas. These are ideas that have commercial promise but have not been reduced to practice, or have not demonstrated that the basic concept has merit at the

"bench" level. Technology maturation funds are used to develop late-stage technologies that are closer to commercialization.

Brookhaven National Laboratory Technology Maturation Fund

- **Start year**: 2007
- **Project selection**: The BNL Office of Technology Commercialization and Partnerships issues annual and semiannual calls for technology maturation proposals. The awards are approved by a cross-functional panel that assesses proposals against a set of maturation selection criteria, intended to validate the deployment potential and strategic impacts of the technology.
- **Source of funding**: A portion of the laboratory's share of royalty income; amount allocated to maturation varies by year, depending on net income of royalties received.
- **Annual funding and number of projects**: Typically funds 5–8 projects out of ~10–15 proposals; the typical amount per project ranges from $50,000 to $100,000. BNL will fund bigger projects to advance technology readiness level, (including research and development, scale-up, and equipment purchase), but these need to be strongly justified. The majority of proposals submitted meet the primary selection criteria, and generally, more funding is sought than can actually be made available through the technology maturation program.
- **Challenges**: Maintaining an appropriate level of funding for technology maturation versus other uses of royalty funds
- **Metrics**: Technologies commercialized, start-up businesses created, research and development (R&D) partnerships developed, follow-on funding achieved.
- **Success story**: Matured a technology that reduces platinum loading in fuel cells and catalytic converters. The maturation project resulted in a process scale-up for the technology and made the product available in quantities suitable for commercial product development and testing. This encouraged a major automotive company to provide research support through CRADAs, which resulted in a commercial license with a leading global catalyst company.
- **Other**: BNL is evaluating a new privately funded technology transfer program structure that would use a management and operations (M&O) contractor and external funding sources for running the program, which could provide additional opportunities for funding technology maturation.

Lawrence Berkeley National Laboratory Technology Innovation Grants Program Technology Maturation Program

- **Start year**: 2011
- **Project selection**:
  - LBNL promotes the program broadly through brown bag information sessions at several sites within the laboratory. LBNL also publicizes through the scientific divisions and the laboratory's daily e-newsletter.
  - Business development staff of Technology Transfer and Intellectual Property Management (TTIPM) meet and internally review all applicants. TTIPM staff work with applicants to identify missing market or commercialization information to better understand the impact of the proposed work. TTIPM then creates a short list of the most promising proposals. These are then evaluated by an external review committee, including venture capitalists and industry. Review ratings are presented to the laboratory deputy director, who makes the final decision.
  - Criteria for proposal selection:
    - Is there sufficient market size to attract entrepreneurial or industry investment?
    - Does the technology offer significant benefits over competitive alternatives?
    - Is the technology perceived by industry as too risky without further evidence?
    - If successful, are the proposed development milestones likely to help attract a licensee?
- **Source of funding:**
  - Portion of licensing royalty revenues managed by the laboratory director.
- **Annual funding and number of projects**:
  - 2011: $400,000 awarded for 4 projects, ($100,000 each) chosen from 48 applications.
  - 2012: $500,000 awarded for 7 projects, ($35,000 to $100,000 each) chosen from 29 applications.
  - About 3 to 4 projects are not funded each year that meet the criteria.
- **Challenges**: Lack of funding support from the DOE.

- **Metrics**:
  - Was the proposed work completed successfully?
  - Was the proposed work completed within the budget provided?
  - Was the technology licensed within 2 years of the completion of the funded work?
- **Success story**: Two of the 2011 Innovation Grant winners are in the process of forming start-up companies and licensing the technologies from the laboratory. One is working on energy efficient electrochromic windows. The other is developing a high-throughput biological assay device. The 2011 winners were able to leverage the Innovation Grants to help win two Small Business Innovation Research (SBIR) grants, an Advanced Research Projects Agency–Energy (ARPA-E) grant, and a corporate-sponsored business competition out of over 120 entries.
- **Other**:
  - Technology transfer staff meet with awardees throughout the project to provide commercialization advice and ensure that industry information is continuing to inform the technology development process.
  - The ideal size of the program is $1 million to $2 million per year.

Lawrence Livermore National Laboratory Technology Maturation Program

- **Start year**: 2010
- **Project selection**:
  - The LLNL Technology Maturation Program is a joint effort between LLNL, who has and understands the technologies, and business entrepreneurs, who understand the market needs, opportunities and business requirements. This joint effort has a higher probability of generating a commercial success than either party attempting to do so on their own.
  - LLNL works with approximately 20+ Silicon Valley entrepreneurs and 80+ angel investors who regularly review laboratory technology. These reviews are done through regular meetings at LLNL and monthly webinars introducing a new technology to the entrepreneurial business community. An interested entrepreneur who has done their due-diligence on the technology and its potential market opportunity may then obtain an option to license the technology, and,

- An entrepreneur may obtain a six month $1,000 option to explore the technology and market opportunities
- If there is market potential, but there needs to be additional work done to "mature" the technology and further prove its potential, the Entrepreneurs/Angel Investors may have additional work done by LLNL in the form of a prototype or other technology demonstration. This is work that the entrepreneur deems to be necessary to validate commercial viability. The demonstration is defined by the entrepreneur but executed by LLNL.
- If LLNL concurs with the proposed work, then it spends LLNL Technology Maturation funds to develop the prototype/demonstration. If successful, the entrepreneur than has the option to license and commercialize the technology.
- The important point is that the entrepreneur, who understands the details of the market need, has defined the prototype/demonstration that he/she believes will provide market validation for the technology.
- All technologies available to the entrepreneurs have satisfied our "Fairness of Opportunity " requirements

- **Source of funding**:
  - LLNL royalty and licensing revenue.
- **Annual funding and number of projects**:
  - About $250,000–$300,000 per year.
  - $25,000 to $50,000 per project.
  - 14 projects in the funding queue
- **Challenges**:
  - Technology Maturation funding comes from licensing and royalty (L&R) funds which in FY 2012 were $9.7 million. Those funds go to inventors of the technology, to the Laboratory for research, and to the LLNL Industrial Partnerships Office for items such as Technology Maturation.
  - The amount of L&R funds varies each year because it is based on royalty payments received each year from LLNL's licensees which in turn are driven by the licensees' annual sales.
  - An additional concern is that the patents that generate the largest portion of the royalties begin to expire next year so our Technology Maturation Fund may decrease.

- **Metrics**:
  - Annual licensing and royalty
  - In 2012, the $9.7 million represents just under $400 million in sales of products based on LLNL inventions.
- **Success stories**: Because the Technology Maturation program as described above only started in 2010 there are no significant success stories to report to date, although there are some promising beginnings. It typically takes 5–6 years for a product to be developed, enter the market, and begin to generate significant royalties. However LLNL has a long history of successful commercialization of technology as evidenced by the $9.7 million licensing and royalty figure, the most of any DOE laboratory. See LLNL Entrepreneurs' Hall of Fame for descriptions of 15 such success stories. (https://www.llnl.gov/news/newsreleases/2012/Oct/attach/entrepreneurs.pdf)

Los Alamos National Laboratory Technology Maturation Program

- **Start year**: FY 2003. Ended in FY 2011; plan to restart in FY 2014.
- **Project selection**:
  - LANL researchers submit a two-page proposal to the technology transfer office. The Selection Committee consists of members of the Technology Transfer Division's Technology Management and Development offices. These reviews ensure that each proposal is reviewed and evaluated by staff with expertise in both technology management and technology commercialization. "Proposals are evaluated based on potential return on investment through a license or a CRADA. We consider market opportunity, relevance to industry, technology risk, competitive risk, people risk, and availability of nongovernment matching funds. A letter of interest or support from a company is helpful" (http://www.lanl.gov/orgs/tt/tech_mat.shtml).
  - Short-term, specific, and goal-focused milestones are required—ideally guided by feedback from a potential industrial partner. Examples of milestones include:
    - Constructing a prototype,
    - Measuring the efficacy/efficiency of a prototype,
    - Analyzing the products of a key experiment,
    - Comparing the product with existing products, and
    - Collecting performance data for a new material, process, or apparatus.

- **Source of funding**: $1 million for regional technology maturation; $200 thousand from royalties; $200,000 from appendix N (appendix in M&O contract, that specifies funding for economic and regional activities for technology commercialization) for a maturation fund (used for entrepreneurial training and more recently for technology maturation).
- **Annual funding and number of projects**:
  - Awards were made in the $50,000 to $100,000 range. On average, LANL funded seven projects per year, about half of the number of projects that met the criteria.
  - LANL has not funded any technology maturation projects in the last 2 years because of other demands on the Technology Transfer Division. Since management of LANL changed to a large for-profit entity, patenting costs have doubled. Due to the economic decline, LANL is also paying advanced funding for CRADAs using royalty funding.
  - LANL plans to restart the technology maturation fund in 2014.
- **Challenges**: 3 to 5 years for return on investment to occur (about 30% of awards).
- **Metrics**:
  - Track projects over several years. Every year, look at the technology to see what has changed: Has it led to new innovation disclosures? Has the technology been licensed? Has it led to a CRADA?
  - Examples of metrics tracked for projects funded between 2003 and 2011:
    - $2.8 million invested in 67 projects, 17 technical divisions
    - 17 licensed and optioned technologies
    - 6 CRADAs and 4 non-Federal work-for-others contracts leveraged
    - 9 invention disclosures
    - 6 patent applications
    - 7 regional start-up companies
    - 5 on-going CRADA/licensing discussions
- **Success story**: A natural plant growth stimulant isolated by LANL scientists causes plants to mature earlier with greater yield but no abnormal effects. Technology maturation funds helped prove the material's effectiveness. The technology was licensed to a boutique agrichemical company in California (BIAGRO Western) that commercialized the technology in Europe as Take-Off.

The company was acquired by Verdesian Life Sciences (http://vlsci.com/) and Take-Off has not yet been introduced into the United States.

Oak Ridge National Laboratory Technology Maturation Program

- **Start year**: Long-standing program; re-launched in June 2010.
- **Project selection**:
  - Standing call for proposals.
  - Proposals must be submitted by researcher and commercialization manager; industrial letter of support or options agreement is strongly encouraged.
  - Technology transfer manager approves project; associate laboratory director approves the funding.
- **Source of funding**: Royalty revenue
- **Annual funding and number of projects (averages across years)**:
  - Annual investment: ~$390,000
  - Number of projects: ~8/year
- **Challenge**: Royalty payments are growing but are volatile (e.g., sharp declines in 2008).
- **Metrics**:
  - 35% of technologies funded since June 2010 have been optioned or licensed.
  - An additional 15% of technologies are in late stage license/option negotiations.
- **Success stories (ongoing)**:
  - Superhydrophobic Coating Portfolio
    - Superhydrophobic coating technology developed using Laboratory Directed Research and Development and Defense Advanced Research Projects Agency funding. Invention disclosed in 2005.
    - Received a 2008 R&D 100 Award.
    - Industry workshop in 2011, drawing more than 60 external visitors.
    - Web and YouTube advertising.
  - Maturation project to improve adhesion to polyvinyl chloride (PVC) pipes
    - ORNL now has license agreements with three start-up companies and one fortune 500 company.
    - Maturation investment was part of a comprehensive licensing strategy.

- **Other**: Recommends counting licenses and start-ups as metrics

National Renewable Energy Laboratory Technology Maturation Funds (not a formal program)

- **Start year**: 2008
- **Project selection**: Privately Funded Technology Transfer (PFTT) program is used for patenting, marketing, licensing, and technology maturation of promising innovations generated from government-sponsored research programs. Non-Federal resources used at NREL to advance promising technologies in which a researcher has filed a record of invention; technology transfer staff and scientist asks for funds to advance technology. No formal call for proposals; selection is case by case using a multi-attribute decision model. Industry match is important, but not required.
- **Source of funding**: M&O contractor (Alliance for Sustainable Energy) has pledged $1.75 million in private (i.e., non-Federal funds) to this program between October 1, 2008, and September 30, 2013.
- **Annual funding and number of projects**:
  - Average size of maturation projects is $30,000 to $75,000.
  - As of January 1, 2013, the PFTT portfolio includes 30 separate Records of Invention in 10 distinct portfolios.
  - Total contractor and industry cost share investment in the PFTT program is expected to exceed $2.2 million.
  - New innovations are regularly screened for inclusion into the PFTT program. The number of innovations selected is limited by the current funding available for the program. Since all technology transfer cost are borne by the contractor, cost projections are made to ensure that all maturation, patenting, and licensing costs necessary to support the elected innovations fit within the available program funding. Few if any new technologies will be moved into the program at this point.
  - The PFTT program will end on September 30, 2013, unless extended by mutual agreement of the contractor and the government.
- **Challenge**: Few Federal resources are available to mature promising technologies. In many cases, promising technologies cannot be successfully commercialized without additional technology maturation.

- **Metrics:** The goal of the program is to rapidly move promising innovations to commercial partners. Since 2010, four licenses to PFTT technologies have been executed, and another three agreements are being negotiated.
- **Success story**: NREL's "black silicon" nanocatalytic wet-chemical etch technique is a one-step process creating high-efficiency solar cells based on an innovative anti-reflection approach that significantly reduces manufacturing costs. NREL estimates that its method can reduce processing costs by 4% to 8%, making black silicon competitive. This technology was selected into NREL's Privately Funded Technology Transfer program and was successfully transferred through a license agreement in 6 months. Wet-Chemical Etch was honored with a 2010 R&D 100 Award (http://www.nrel.gov/news/press/2011/1590.html).
- **Other**: Technology maturation funds help reduce technology and business risk.

Pacific Northwest National Laboratory Technology Maturation Program

- **Start year**: 2005
- **Project selection**: The PNNL Technology Maturation Program (TMP) evaluates and makes investments to mature various technologies that are developed by PNNL staff to improve the potential for transferring the technologies to the commercial marketplace. PNNL commercialization staff consider several criteria when making maturation investment decisions. The criteria considered include but are not limited to the commercial potential of a technology, interest and feedback expressed by potential licensees and investors, and the feasibility to achieve performance requirements for adoption by commercial entities. Cost sharing and cooperative funding with third parties is considered a positive factor.
- **Source of funding**: Funds for the PNNL technology maturation program were generated or received from multiple sources. The bulk of funds were generated as Independent Research and Development (IR&D) overhead recovered from projects performed under the now expired Use Permit. Other sources that contribute to maturation funds include "use at facility funds" consisting of 51% of the net royalties received under the PNNL privately funded technology transfer program, 100% of net royalties under the PNNL government-funded technology transfer program, and third-party cost-sharing or cooperative funds that were contributed predominantly under mechanisms that were formerly available via the Use Permit. Additionally, Battelle Memorial Institute (Battelle), the PNNL operating contractor, contributed private (unrecovered) resources for technology maturation projects through corporate-funded IR&D activities facilitated by Use Permit mechanisms.

- **Annual funding and number of projects**:
  - PNNL has funded about 70 technology maturation projects per year. Funding for the projects (including IR&D funding) has historically varied from $50,000 to $400,000 per project with the higher cost projects being funded by corporate IR&D. Typical costs for technology maturation projects that were not funded by corporate IR&D tend to average about $75,000 per project.
  - Approximately 30 to 35 technology maturation projects per year have not been funded at PNNL due to lack of funds previously provided under the now-expired Use Permit.
- **Challenges:** Historically, the maturation program was composed of $2.6 million of PNNL managed funds (excluding corporate IR&D) that were annually dispersed for PNNL technology maturation projects. Upon expiration of the Use Permit, a portion of the previous resource for technology maturation funding was no longer available. Accordingly, the PNNL maturation program did not have an alternative funding source available to replace the approximately $1.6 million in funds generated under the Use Permit, unless a viable alternative was identified under the PNNL M&O contract. PNNL relied upon authorizations found within the Department of Energy Acquisition Regulation[8]—which are also incorporated into the PNNL M&O contract—to allocate a portion of existing overhead funds for PNNL technology maturation activities. Although the post-Use Permit technology maturation program was projected to have only one-third of the funds it historically dispersed without the reallocation of

---

[8] 48 CFR 970.5227-3(A)(2) states:

> In pursuing the technology transfer mission, the Contractor is authorized to conduct activities *including but not limited to*:…It is fully expected that the Contractor shall *use all of the mechanisms available* to it to accomplish this technology transfer mission, *including, but not limited to*, CRADAs, user facilities, WFO, science education activities, consulting, personnel exchanges, assignments, and licensing in accordance with this clause. (Emphasis added.)

48 CFR 970.5227-3(C)(1) states:

> The Contractor shall establish and carry out its technology transfer efforts through appropriate organizational elements consistent with the requirements for an Office of Research and Technology Applications (ORTA) pursuant to paragraphs (b) and (c) of Section 11 of the Stevenson-Wydler Technology Innovation Act of 1980, as amended (15 U.S.C. 3710). The costs associated with the conduct of technology transfer through the ORTA including activities associated with obtaining, maintaining, licensing, and assigning Intellectual Property rights, *increasing the potential for the transfer of technology*, and the widespread notice of technology transfer opportunities, shall be deemed allowable provided that such costs meet the other requirements of the allowable costs provisions of this Contract. (Emphasis added.).

overhead, the DOE instructed PNNL to cease reallocation of overhead funds for technology maturation purposes.

- **Metrics:** Metrics vary over the period the program has been in effect. Metric topical areas include commercial adoption or licensing of the matured technology and generation of new intellectual property, business opportunities, sponsors, and participants.
- **Success story:**
  - One of PNNL's most visible technology transfers is the millimeter-wave body scanner that is widely used by the Transportation Safety Administration at airports throughout the United States. This technology was originally developed at PNNL before 2000, but 9/11 suddenly created a demand for a non-radiating scanning technology. Technology maturation funds from Battelle were used to optimize the algorithms required to address privacy concerns, thus facilitating a license to fully deploy and commercialize the technology. Other applications for this technology (e.g., the commercial garment industry) have also emerged.
- **Other:** The IDEA model of technology transfer has the goal of getting researchers thinking about potential commercial goals or output at early stages of research activities. Although the idea is not to replace the conduct of basic science and research pursuits, PNNL believes it is important in introduce proactive thinking about intellectual property and commercialization opportunities at the earliest possible stages of the research equation.

Sandia National Laboratories

- Participated in EERE's Technology Commercialization Fund in 2007−2008; no current program.

Appendix D.
Descriptions of Technology Maturation Funds at Selected Universities

Cornell University

- **Program**: Although Cornell's Center for Technology Enterprise and Commercialization does not have a maturation fund, Cornell has a Center for Advanced Technology in Biotechnology that spends some of its money on moving technologies forward.
- **History**: This fund, dedicated solely to biotechnology, has been around for 20 years. It was originally founded because the State of New York perceived a large gap between university discovery and company adoption in the life sciences.
- **Funding details**: Total fund is about $100,000 to $200,000 a year. Each project is normally funded with about $50,000 (implies between 2 to 4 projects per year). The program could use more funding.
- **Selection criteria and process**: Cornell sends out a request for proposals with a focus on maturation. Goal of projects is usually to increase the amount of data behind new science.
- **Metrics:** Number of technologies commercialized.
- **Website:** http://www.biotech.cornell.edu/.

Harvard University

- **Program**: Biomedical Fund Accelerator.
- **History**: Fund began in 2007. Program is currently undergoing an expansion in size; will potentially expand to fund a wider range of therapeutics, including personalized/regenerative medicine.
- **Funding details**: The fund started out with $2 million, and funded 4–6 projects for 1–2 years each (at an average of about $100,000 per project). After the expansion, the program will also select 1–2 multi-year projects whose total funding might be closer to $1 million each. Harvard is willing to fund 2–3 more projects given the funding.
- **Source of funding**: Philanthropic donation (Harvard graduates).

- **Selection criteria and process**: Open call. Proposals are evaluated on freedom to operate, market size and interest, clear development path, and whether the ~$250,000 will be impactful. Also looking to see whether the principal investigators (PIs) are cooperative and would be willing to speak to companies about what they want to see. The fund receives about 30 pre-proposals and 12–15 full proposals each year.
- **Metrics**: Conversion rates of projects to partnerships, amount of money brought in for sponsored research or through licensing revenue (long term), number of projects that are licensed.
- **Success stories**: Two professors identified proteins that had potential to inhibit cell degradation associated with Alzheimer's disease. Industry was intrigued but not willing to invest. The fund supplied a relatively large investment ($350,000 in accelerator funds plus $150,000 from an angel investor) to improve the protein compounds, make them more drug-like, and conduct animal testing. A year later, the project was licensed to a local biotech company, which also brought on the professors as directors and made the project their central activity. "We took something that was un-licensable and with a fairly modest investment were able to make it interesting to companies and get research on this."
- **Other**: The technology maturation program has benefited Harvard on the whole because it has improved how the faculty thinks about commercialization. It is important when setting up a maturation fund to consider the type of technologies that one wishes to support as that affects its sustainability from royalty revenues.
- **Website**: http://www.techtransfer.harvard.edu/techaccelerator/acceleratorfund/.

Iowa State University

- **Program**: Iowa State University Research Foundation Grant Program.
- **History**: The program has existed for about 4 years. The goal of the fund is to push technology closer to licensing or creating a start-up, or prototype development.
- **Funding details**: Fund size is about $1 million, with range from $5,000 to $100,000 thousand per project.
- **Source of funding**: State government (funds for economic development) and the university.
- **Selection criteria and process**: They host a request for proposals each year that requires a short proposal. Selection is aided by 10 students from the entrepreneurial center. They look for the likelihood of the science being successful and for the potential outlook of the market (when the PI plans to

commercialize, etc.). Cost sharing is not required, but considered important for indicating market potential. The university funds about 1/3 of the proposals received.

- **Metrics**: Number of start-ups, licenses, options, third-party validation, tracking projects over the life-cycle.
- **Success stories**: About 20 start-ups, one with $6 million in clinical trials.
- **Other**: Creates employment for some graduates who are running out of grant funding. Program also includes commercial mentoring for PIs.
- **Website:** http://www.techtransfer.iastate.edu/index.cfm?nodeID=21440.

Johns Hopkins University

- **Program**: Johns Hopkins University (JHU) Maturation Fund (former); Maryland Innovation Initiative (current).
- **History**: JHU had a maturation fund in 1980s as a response to Bayh-Dole Act; however, the fund lacked an oversight board that had an understanding of the market. More recently, the State of Maryland opened up a new fund for companies, and JHU has submitted 8 proposals.
- **Funding details**: The State of Maryland funds a technology transfer program by collecting funding from each of the six universities, matching those funds and then distributing across six universities, not necessarily proportional to their contribution. JHU contributed $250,000; the University of Maryland contributed $250,000; and other universities contributed other amounts (6 universities involved). The total fund is around $5 million.
- **Source of funding**: Universities, state government
- **Selection criteria and process**: Not specified.
- **Metrics**: JHU researches work on high risk R&D that often take a long time to produce outputs and outcomes.
- **Other:** “0.25–0.5% of every grant could be specifically directed to the TTO [technology transfer office], not for expenses in the office but to be deployed slowly for additional research to advance the technology down the commercialization path. That would be the single most effective program the Federal Government could have to advance technology.”

Massachusetts Institute of Technology

- **Program**: Deshpande Center.

- **History**: The fund has existed for 10 years since its creation through a $20 million donation from Mr. Deshpande to foster entrepreneurship in the Boston area. In addition to funding, the program also provides external entrepreneurial support to help the inventor define the market.
- **Funding details**: Two levels of grants: Ignition ($50,000 to $100,000) and Innovation (up to $250,000). Both are one-year grants. Fund allows for about $1 million a year. The center funds about 12 projects a year; money is beginning to run out so fewer are being funded (8 in 2012). With more funds, the fund could support a dozen new grants.
- **Source of funding**: Philanthropic donation from one individual.
- **Selection criteria and process**: Open call. Criteria for selection are good science and market potential. They are not concerned about how close the technology development is to the market.
- **Metrics**: Number of company spin-outs; attraction of additional investment funds; limited focus on licenses
- **Success stories:** See http://deshpande.mit.edu/portfolio/case-studies.
- **Other:** Federal laboratories might have to take technologies further because there is less movement of people with the technologies, which MIT views as central to technology transfer. DOE scientists are less likely to commercialize their technologies directly by creating a startup or joining a firm to do so.
- **Website:** http://deshpande.mit.edu/.

Princeton University

- **Program**: Intellectual Property Accelerator Fund.
- **History**: The fund is designed to foster a proof of principal, spur development, or bring technology across the valley of death so that the IP is in a better position to attract a start-up or license. The first iteration of the fund was 2004–2007, funded by the New Jersey Commission of Science and Technology. The fund was discontinued and then revitalized by Princeton in 2011.
- **Funding details**: $0.5 million dollars in the fund with some flexibility. Grantees received $50,000 to $100,000 for one year. Proposals can specify an amount, but the committee determines the amount of funds awarded. Last year 9 projects were funded, and 4 to 6 projects are expected to be funded this year.
- **Source of funding**: Internal university funds (general). Amount varies on a year-to-year basis.

- **Selection criteria and process**: Proposals are peer reviewed by a review committee chaired by the dean of research and comprising faculty members and two outside VCs. Technology transfer office serves an advisory role to the selection committee. Review categories are scientific/technical merit and technology transfer potential. In 2012, the fund received 23 proposals.
- **Metrics**: Princeton follows-up with individuals on a one-on-one basis and will do this for the first iteration soon.
- **Success stories:** Three technologies bring in over $1 million a year in royalties, although Princeton does not prioritize royalties as a goal.
- **Other:** Technologies that do not win funding are still marketed by the university. Views their program as a public service for a faculty, who "being raised in the era of Bayh-Dole" are looking to get their technologies out into the public. The program is also a service for companies and investors looking to develop a long-term relationship.
- **Website:** http://www.princeton.edu/patents/ipa/.

University of Michigan (Two Programs)

Program 1: Translational Research Programs

- **History**: Translational research funds have been around for several years in the form of various programs that entail internal maturation at the laboratory. This research is focused on refining a prototype or proving a concept related to an application. One example is the Coulter Fund for Biomedical Research, which is about 6–7 years old.
- **Funding details**: The fund began with $0.25 million and has grown to about $1 million at present with plans to grow the fund to $1.5 million. Typically fund projects with $25,000 to $100,000 for 2 years. The fund can support about 10–12 grants, other translational funds at the university typically fund 5–10 projects. The fund could be expanded to fund more projects.
- **Source of funding**: Largely endowment funds.
- **Selection criteria and process**: Selection criteria are primarily technical validity and market need.
- **Metrics**: Outcomes of licenses and start-ups, but these measurements will not be relevant until 5–8 years after a project is funded.
- **Success stories:** HistaSonics (University of Michigan News Service 2010)
  - University of Michigan inventors secured $11 million in financing to launch HistoSonics Inc., which will develop a medical device that uses tightly

focused ultrasound pulses to treat prostate disease. Histotripsy is a non-invasive, image-guided system that ablates tissue with robotic precision. The $11 million Series A financing is led by Venture Investors of Ann Arbor and Madison. To get the technology to this stage required at least two rounds of maturation funding:

  - The Office of Technology Transfer and the Coulter Translational Research Partnership at the Department of Biomedical Engineering provided funds and expertise that helped the project leader and his colleagues guide their invention to the marketplace.
  - The Office of Technology Transfer provided gap funding through its Michigan Venture Center and advised the team on commercialization, patenting and licensing issues. Tech Transfer's Mentors-in-Residence program also contributed to the project's success.

- **Website:** http://www.techtransfer.umich.edu/resources/venturecenter/gapfunding.php.

Program 2: Gap Funding

- **History**: The original goal of the program was to take money to address small market issues for emerging research. Gap funding comes from the technology transfer office and has been around about 10 years. Whereas translational research is done more exclusively by researchers, gap funding involves potential licensees directly.
- **Funding details**: Fund is about $800,000 and can support about 20 projects. In some cases, grants are as small as $5 thousand, which can help answer a targeted question for a technology.
- **Source of funding**: University and state funding, also supported through reinvestment of royalties/licensing revenues.
- **Selection criteria and process**: Commercial potential; often the gap funding is directed at answering the question about whether they should patent, license, or redirect their focus.
- **Metrics**: Life-cycle focus on tracking outputs and outcomes; study both successes and "failures," for example, at Michigan, a maturation investment that shows that the technology does not have market potential is considered a success because investment is then directed elsewhere.
- **Website:** http://www.techtransfer.umich.edu/resources/venturecenter/gapfunding.php.

References

Argonne National Laboratory (ANL). Undated. "Technical Assistance Helps Company Avoid Production Shutdown." *Technology Development and Commercialization.* no. http://web.anl.gov/techtransfer/Industrial_Relationships/CloverClub.html.

Auerswald, P. E. , and L. M. Branscomb. 2003. "Valleys of Death and Darwinian Seas: Financing the Invention to Innovation Transition in the United States." *Journal of Technology Transfer* no. 28 (3–4):227–239.

Barr, S. H., T. Baker, S. K. Markham, and A. I. Kingon. 2009. "Bridging the Valley of Death: Lessons Learned From 14 Years of Commercialization of Technology Education." *Academy of Management Learning & Education* no. 8 (3):370–388.

Branscomb, L. M. , and P. E. Auerswald. 2002. Between Invention and Innovation: An Analysis of Funding for Early-Stage Technology Development. Gaithersburg, MD: Department of Commerce, National Institute of Standards and Technology.

Department of Energy (DOE). 1996. *Laboratory Technology Research: Abstracts of FY 1996 Projects*. Vol. DOE/ER-0702. Washington, DC: DOE.

———. 1997. *Laboratory Technology Research: Abstracts of FY 1997 Projects*. Vol. DOE/ER-0714 Washington, DC: DOE.

———. 1998. *Laboratory Technology Research: Abstracts of FY 1998 Projects*. Vol. DOE/ER-0737. Washington, DC: DOE.

Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE). *Technology Commercialization Fund* 2012. Available from http://techportal.eere.energy.gov/commercialization/technology_commercialization_fund.html.

Government Accountability Office (GAO). 2009. *Technology Transfer: Clearer Priorities and Greater Use of Innovative Approaches Could Increase the Effectiveness of Technology Transfer at Department of Energy Laboratories*. Washington, D.C.: GAO. GAO-09-548. http://www.gao.gov/assets/300/290963.pdf.

Harvard University. *Harvard Biomedical Accelerator Fund Request for Proposals* 2013. Available from http://www.techtransfer.harvard.edu/faculty/Biomedical_Accelerator_Guidelines_2013.pdf.

Lambert, Jack. 2012. Maryland Innovation Initiative Awards $300,000 in Grants. *Baltimore Business Journal*, December 19. http://www.bizjournals.com/baltimore/news/2012/12/19/maryland-innovation-initiative-awards.html.

Mott, J. 2011. Sustainable Technology Commercialization Gap Funds. edited by M. (moderator) Allen. 2011 Federal Laboratory Consortium National Meeting. May 3, 2011. Nashville, TN.

National Renewable Energy Laboratory (NREL). 2011. "Federal Laboratory Consortium Highlights Three NREL Research Projects." *NREL News Release.* no. NR-4711. http://www.nrel.gov/news/press/2011/1590.html.

Payne, T. L., and C. Kniel. 2000. *A Survey of LTR Program Industry Partner Satisfaction at Oak Ridge National Laboratory*. Oak Ridge, TN: Oak Ridge National Laboratory.

PricewaterhouseCoopers. *MoneyTree Report* 2013. Available from https://www.pwcmoneytree.com/MTPublic/ns/moneytree/filesource/displays/notice-B.html.

Redwine, S. T., and W. E. Riddle. 1985. "Software Technology Maturation." In *8th IEEE/ACM International Conference on Software Engineering*, 189–200. London, UK.

Stokes, D. 1997. *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, DC: Brookings Institution Press.

University of Michigan News Service. *U-M Spinoff HistoSonics Secures $11 Million in Financing to Develop Disease-Fighting Ultrasound Technology* 2010. Available from http://ns.umich.edu/new/releases/7471.

Wang, M., S. L. Pfleeger, D. M. Adamson, G. Bloom, W. Butz, D. Fossum, M. Gross, A. Kofner, H. Rippen, T. K. Kelly, and C. T. Kelley Jr. 2003. *Technology Transfer of Federally Funded R&D*. Santa Monica, CA: RAND Science and Technology Policy Institute.

Yarris, L. *AMTEX Textile Alliance*, March 26, 1993. Available from http://www.lbl.gov/Science-Articles/Archive/amtex-textile-alliance.html.

Abbreviations

ANL	Argonne National Laboratory
BNL	Brookhaven National Laboratory
CRADA	Cooperative Research and Development Agreement
DOE	Department of Energy
DOE/ER	Department of Energy Office of Energy Research
EERE	Office of Energy Efficiency and Renewable Energy
FY	fiscal year
I-Corps	Innovation Corps
IDA	Institute for Defense Analyses
IP	Intellectual Property
IR&D	Independent Research and Development
JHU	Johns Hopkins University
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LDRD	Laboratory Directed Research and Development
LLNL	Lawrence Livermore National Laboratory
LTR	Laboratory Technology Research Program
M&O	management and operations
MIT	Massachusetts Institutes of Technology
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
ORNL	Oak Ridge National Laboratory
OSTP	Office of Science and Technology Policy
PFTT	Privately Funded Technology Transfer
PI	principal investigator
PNNL	Pacific Northwest National Laboratory
PVC	polyvinyl chloride
R&D	research and development
SNL	Sandia National Laboratories
SBIR	Small Business Innovation Research
STPI	Science and Technology Policy Institute
TCF	Technology Commercialization Fund
VC	venture capitalist

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
XX-05-2013	Final	Nov 2012 - May 2013

4. TITLE AND SUBTITLE Department of Energy Technology Maturation Programs	**5a. CONTRACT NUMBER** NSFOIA0408601/STPIAK
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Howieson, Susannah V. Sedenberg, Elaine M. Sergi, Brian J. Shipp, Stephanie S.	**5d. PROJECT NUMBER**
	5e. TASK NUMBER STPI-0400.00.AK (TP-20-1000)
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Science and Technology Policy Institute 1899 Pennsylvania Avenue, NW, Suite 520 Washington, DC 20006-3602	**8. PERFORMING ORGANIZATION REPORT NUMBER** IDA Paper P-5013
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Science and Technology Policy Executive Office of the President Eisenhower Executive Office Building 1650 Pennsylvania Avenue Washington, DC 20504	**10. SPONSOR/MONITOR'S ACRONYM(S)** OSTP
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited (22 May 2013).

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Technology maturation programs are designed to provide a link between laboratory research and development products and specific market needs. For any laboratory invention, additional development or testing may be necessary before an outside party will be willing to license and commercialize the technology. IDA Science and Technology Policy Institute researchers conducted a review of relevant academic literature and government documents and interviewed individuals from DOE headquarters, the national laboratories, and universities. This report discusses the history and implementation of technology maturation programs and documents the types and characteristics of projects funded, the criteria to select the projects, and the metrics to track the success of these projects. Both the Federal and university programs provide ideas for creating a DOE-wide program as well as methods for DOE laboratories wishing to enhance their existing programs.

15. SUBJECT TERMS

technology maturation, technology acceleration, valley of death, Department of Energy (DOE), national laboratories, technology transfer, intellectual property, Laboratory Technology Research (LTR) program, Technology Commercialization Fund (TCF), proof-of-concept, prototype, commercialization

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Maynard, Nick
Unclassified	Unclassified	Unclassified	Same as Report	59	**19b. TELEPHONE NUMBER** *(Include area code)* 202-456-6069