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Technology Transfer and Commercialization Landscape of the Federal Laboratories

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Executive Summary

Federal laboratories have been a source of innovation in the United States since the establishment of the first laboratory, the Smithsonian Institution, in 1846. The Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480) stated, “technology transfer, consistent with mission responsibilities, is a responsibility of each laboratory science and engineering professional.” The act mandated the creation of an Office of Research and Technology Applications at major laboratories to facilitate transfers of technology from the laboratories. Since then, interest in increasing the intensity and effectiveness of technology transfer has focused on activities that accelerate commercialization to benefit the economy and society.

While academic researchers have studied the topic of technology transfer from the federal laboratories at length, many of the studies were completed before 2000, and substantial changes have occurred since then in the national and global economic landscape. Furthermore, past studies examined a small subset of agencies’ laboratories, minimizing the broad range of federal laboratories and their technology transfer activities. These studies are insufficient to understand the issues surrounding the transfer of technology and the commercialization of products and processes from the federal laboratories as a whole.

Against this backdrop, the Department of Commerce, Economic Development Administration, in conjunction with the National Institute of Standards and Technology, asked the IDA Science and Technology Policy Institute (STPI) to study the landscape of technology transfer and commercialization at the federal laboratories to serve as a baseline for further action.

The study began with a literature review that informed the approach to discussions with technology transfer personnel at federal agencies and laboratories. These discussions, the primary mode of data collection, were held with representatives from 13 agencies and subagencies, 26 laboratories, and 33 other organizations.

These discussions provided an understanding of technology transfer and commercialization activities at the laboratories, identified perceived barriers to technology transfer, and uncovered strategies with potential for overcoming these barriers. They also revealed factors that affect the speed and dissemination of technologies from the laboratories.

Defining Technology Transfer and Commercialization

A critical step in the study was to develop a definition of technology transfer and commercialization. Technology transfer and commercialization can occur along three pathways.

- The direct pathway results in the exchange of products or processes, or collaborative research for developing technologies, between laboratories and other parties.
- The indirect pathway results in dissemination of knowledge through such mechanisms as publications, conferences, and teaching.
- The network pathway creates networks that may facilitate transfer through one of the other pathways and can accelerate movement along the trajectory of technology transfer to commercialization.

The primary interest of this study is in technology transfer that leads to commercialization. Therefore, the study's focus is on the direct pathway and the network pathway.

The direct pathway involves three types of technology transfer, based on the producer of the technology, the mechanism of transfer, and the user of the technology. They are:

- *Commercial transfer* of technology from a federal laboratory or agency (the producer) to a commercial organization (the user) that can improve technologies by undertaking the technical, business, and manufacturing research to bring them to market. *Dual use*, a subset of commercial transfer, refers to the development of technologies, products, or families of products that have both commercial and federal government applications. The producer is the laboratory or agency, and the user is both the government and industry.
- *Exporting resources* occurs when the federal laboratory or agency (the producer) provides expertise to outside organizations, including industry, academia, and state and local governments, or to other federal laboratories and agencies (the user).
- *Importing resources*, also called "technology transition" or "spin-in," describes the process of a federal laboratory or agency engaging in a cooperative effort that brings technology created by an external entity (the producer) into the agency (the user) to enhance the laboratory or agency's efforts.

Legislation provides federal laboratories with a variety of mechanisms for accomplishing these activities, but not all laboratories have the same legal authorities to use them.

Factors that Affect Technology Transfer and Commercialization at Federal Laboratories

From our interviews with technology transfer personnel in agencies and laboratories, nine mutually influential factors were identified that appear to affect the speed and extent of dissemination of technologies transferred from federal laboratories to the private sector. They are:

1. *Laboratory mission.* Technology transfer varies across laboratories due to the diversity and scope of their missions. Some laboratories are more inclined towards technology transfer that leads to commercialization because it is in the interest of achieving the mission of the laboratory, agency, or subagency.
2. *Laboratory management.* Differences between Government-Owned, Government-Operated (GOGO) and Government-Owned, Contractor-Operated (GOCO) laboratories can affect technology transfer and commercialization activities. GOCO laboratory leadership is often explicitly tasked to perform technology transfer and commercialization, while GOGO laboratories must comply with certain government regulations that do not affect GOCOs.
3. *Congressional support and oversight*. Despite congressional support for technology transfer at the federal laboratories, congressional action and oversight can have the unintended consequence of encouraging a risk-averse culture towards technology transfer. Furthermore, technology transfer activities can be undermined when congressional priorities shift, as technology transfer requires long-term support.
4. *Agency leadership and laboratory director support*. Support from agency leadership and laboratory directors can have a marked effect on technology transfer and commercialization activities. For example, laboratory directors who support technology transfer may provide resources, flexibility, and creative license to their ORTAs. Those ORTAs who are not supported by their laboratory leadership can be severely constrained.
5. *Organization and coordination of technology transfer and commercialization activities*. The centralization/decentralization of technology transfer functions at the agency and laboratory levels affects the speed of implementation of technology transfer actions, the consistency of policies across laboratories within an agency, and the ability to share best practices. The location of ORTAs within an agency and laboratory can affect the visibility of technology transfer.
6. *Offices of Research and Technology Applications*. Operations that seem to affect technology transfer and commercialization include the responsibilities of the office; the science, technology, and business expertise of the staff; the processes

of the office; and the legal authorities available to the laboratory and how ORTA staff interpreted them.

7. *Researchers.* Laboratory researchers, whose participation in technology transfer and commercialization processes varies across laboratories, may lack the knowledge, ability, and incentives necessary to undertake the research, administration, and business development involved in successful technology transfer.

8. *Government-industry interactions.* Federal laboratories are not visible and accessible to industry, and certain regulations make it difficult for federal laboratories and industry to interact. According to partnership intermediaries, groups designed to broker partnerships between the laboratories and industry, industry is largely unaware of opportunities to collaborate with the federal laboratories.

9. *Resources.* Resources devoted to technology transfer and commercialization vary across laboratories and agencies. Further, the extent to which the agencies and laboratories leverage federal, state, and local programs that support technology-based economic development may also affect technology transfer and commercialization.

Innovative Strategies Observed at the Laboratories

Interviewees reported using innovative strategies believed to increase the speed and extent of dissemination of technology transfer that leads to commercialization. Although it was beyond the scope of this study to evaluate the effectiveness of these strategies, interviewees suggested they could be useful to the laboratories or agencies as they pursue technology transfer and commercialization.

- Collaborate with universities.
- Increase laboratory director involvement in technology transfer activities.
- Strengthen or complement the skill set of the Office of Research and Technology Applications staff.
- Enhance education and incentives for researchers to engage in technology transfer.
- Use standardized agreements to streamline industry interactions.
- Increase visibility and access to federal laboratories by increasing outreach and use of partnership intermediaries.
- Increase availability of resources through leveraging economic development and commercialization programs and partnership intermediaries.

Defining and Measuring Success

The development of appropriate metrics depends on a clear statement of a program's desired outputs and outcomes, and metrics can be used for a variety of purposes. Because of the diversity of goals across the federal agencies and laboratories, it is difficult to come up with a single set of metrics for the entire portfolio of federal laboratories. Given this challenge, we propose the inclusion of process or activity metrics that can describe technology transfer within the diverse missions.

Different stakeholders have an interest in metrics on technology transfer that leads to commercialization from the laboratories, and it is not clear that the metrics currently collected (in the interagency summary report to the President and Congress on technology transfer at the federal laboratories) meet the needs of all those stakeholders. Although additional metrics are desired, especially for describing outputs and outcomes, the burden associated with collecting additional metrics should not be overlooked. Such metrics can be expensive to collect and difficult to attribute to a single laboratory, and they may not reflect the success of a technology transfer program.

Most laboratory ORTA personnel could not provide a clear definition of what success means to their laboratory. Without this definition, laboratories are unable to measure whether they are accomplishing their goals.

Data on technology transfer activities, outputs, and outcomes are not readily available at the laboratory level, and this lack of data prohibited the study team from making any descriptive statements about laboratory-level technology transfer that leads to commercialization.

Conclusion and Areas for Further Study

This landscape study describes the technology transfer and commercialization activities, barriers, and current measures of success at federal laboratories. It is the first systematic study of technology transfer at federal laboratories published since the early 2000s. This study covers a larger number of diverse laboratories than the previous studies.

Since the passage of the Stevenson-Wydler Technology Innovation Act of 1980, federal laboratories have adopted many innovative strategies to transfer technology to the private sector with the ultimate goal of commercialization. Many agencies and laboratories have streamlined their technology transfer processes and increased their outreach activities through the use of partnership intermediary organizations with the goal that industry will know that they are "open for business." However, barriers to technology transfer and commercialization remain.

This study identified areas related to enhancing and accelerating federal laboratory technology transfer and commercialization that would benefit from further study. Among them are:

- Study technology transfer at federal laboratories systematically and regularly to better understand technology transfer and commercialization activities across the laboratories. This would allow for ongoing evaluation of innovative strategies and their suitability for adoption by other laboratories.
- Study the perspectives of researchers, laboratory directors, and others within the laboratories view technology transfer and evaluate the level of alignment between technology transfer and laboratory mission.
- Delve further into barriers to effective technology transfer and desirable reforms.
- Review technology transfer legal authorities to assess which of them should be extended to all laboratories.
- Analyze the legal agreement language used by the laboratories to understand how successful negotiations deal with these provisions and whether guidelines can be provided to laboratories and industry when negotiating agreements.
- Collect technology transfer data at the laboratory level for a more sophisticated portfolio analysis of technology transfer occurring at the federal intramural laboratories.
- Analyze existing technology-based federal, state, and local economic development programs and how laboratories could leverage these programs to enhance technology transfer that leads to commercialization.

A fuller understanding of the landscape of technology transfer and commercialization requires knowing the perspective of researchers, laboratory directors, industry participants, and others. Meanwhile, several strategies are in place at some laboratories that other laboratories may find useful to replicate. Further, several new process metrics could be implemented to assist laboratories in improving their technology transfer to commercialization systems and defining the success of these activities.

Abbreviations

AFRL	Air Force Research Laboratory
AMRMC	Army Medical Research and Material Command
ANL	Argonne National Laboratory
APLU	Association of Public and Land-Grant Universities
ARDEC	Army Armament Research, Development and Engineering Center
ARS	Agricultural Research Service
ATIP	Agricultural Technology Innovation Partnership
AUTM	Association of University Technology Managers
CCEHBR	Center for Coastal Environmental Health and Biomolecular Research
CDC	Centers for Disease Control and Prevention
CIT	Center for Innovative Technology
CRADA	Cooperative Research and Development Agreement
CRS	Congressional Research Service
CRTA	Cancer Research Training Award
DHS	Department of Homeland Security
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOT	Department of Transportation
EERE	Energy Efficiency and Renewable Energy
EPA	Environmental Protection Agency
ESRL	Earth Systems Research Laboratory
ESTT	Entrepreneurial Separation to Transfer Technology
EUL	Enhanced Use Lease
FAA	Federal Aviation Administration
FAA-Hughes	Federal Aviation Administration–William J. Hughes Technical Center
FDA	Food and Drug Administration
FLC	Federal Laboratory Consortium for Technology Transfer
FRA	Federal Railroad Administration
FTE	Full-Time Employees
FTTA	Federal Technology Transfer Act of 1986 (P.L. 99-502)
GAO	Government Accountability Office
GOCO	Government-Owned, Contractor-Operated
GOGO	Government-Owned, Government-Operated
GSFC	Goddard Space Flight Center
HHS	Department of Health and Human Services
HML	Hollings Marine Laboratory

INL	Idaho National Laboratory
IP	Intellectual Property
IRTA	Intramural Research Training Award
ITS	Institute for Telecommunications Sciences
IWGTT	Interagency Working Group for Technology Transfer
JPL	Jet Propulsion Laboratory
JTTI	Joint Technology Transfer Initiative
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LLNL	Lawrence Livermore National Laboratory
MEP	Manufacturing Extension Partnership
MT	Material Transfer
MTA	Material Transfer Agreement
NASA	National Aeronautics and Space Administration
NASVF	National Association of Seed and Venture Funds
NCI	National Cancer Institute
NASVF	National Association of Seed and Venture Funds
NHLBI	National Heart, Lung and Blood Institute
NIAID	National Institute of Allergy and Infectious Diseases
NIDDK	National Institute of Diabetes and Digestive and Kidney Diseases
NIH	National Institutes of Health
NINDS	National Institute of Neurological Disorders and Stroke
NIST	National Institute of Standards and Technology
NNSA	National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NSWC-Crane	Naval Surface Warfare Center Crane Division
OAR	Oceanic and Atmospheric Research
OIE	Office of Innovation and Entrepreneurship
ONR	Office of Naval Research
ORNL	Oak Ridge National Laboratory
ORTA	Office of Research and Technology Applications
OTT	Office of Technology Transfer
OTTPIN	Office of Technology Transfer Partnership Intermediary Network
PIA	Partnership Intermediary Agreement
PNNL	Pacific Northwest National Laboratory
R&D	Research and Development
RITA	Research and Innovative Technology Administration
SBIR	Small Business Innovation Research
SLA	Simplified Letter Agreement
SNL	Sandia National Laboratories
SPAWAR	Space and Naval Warfare Systems Command
SRNL	Savannah River National Laboratory
SAA	Space Act Agreement
STTR	Small Business Technology Transfer program
TCF	Technology Commercialization Fund

TechComm	Technology Commercialization and Manufacturing
TEDCO	Maryland Technology Development Corporation
TRL	Technology Readiness Level
TTCA	Technology Transfer Commercialization Act of 2000 (P.L. 106-404)
TVC	Technology Ventures Corporation
UBMTA	Uniform Biological Material Transfer Agreement
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VA	Department of Veterans Affairs
Volpe	John A. Volpe National Transportation Systems Center
WARF	Wisconsin Alumni Research Foundation
WFO	Work-for-Others (agreement)

Contents

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1. Introduction

Federal laboratories have been a source of innovation in the United States since the establishment of the first laboratory, the Smithsonian Institution, in 1846. The Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480) stated, “technology transfer, consistent with mission responsibilities, is a responsibility of each laboratory science and engineering professional.” In addition, the act mandated the creation of an Office of Research and Technology Applications (ORTA) at major laboratories to facilitate transfers of technology from the laboratories.[1] Since that time, there has been periodic interest in increasing the intensity and effectiveness of technology transfer, with a focus on activities that accelerate commercialization to benefit the economy and society.

A. Study Rationale

The topic of technology transfer from the federal laboratories has been studied at length by academic researchers and has been an interest of Congress and past administrations. However, many of the studies were completed prior to 2000.[2] Since that time, substantial changes have occurred in the economic landscape, both nationally and globally. Furthermore, these past studies generally examined a small subset of agencies' laboratories, minimizing the broad range of technology transfer at the laboratories. These studies are insufficient to understand the issues surrounding the transfer of technology and the commercialization of products from the federal laboratories as a whole.

Against this backdrop, the Department of Commerce, Economic Development Administration (EDA), in conjunction with the National Institute of Standards and Technology (NIST), asked the IDA Science and Technology Policy Institute (STPI) to study the current state of affairs of technology transfer and commercialization at the federal laboratories. This study is a snapshot of technology transfer from the federal laboratories and, thus, is descriptive in nature. The study began with a literature review that informed the approach to discussions with technology transfer personnel at federal agencies and laboratories, which served as the primary mode of data collection. Discussions were held with stakeholders from 13 agencies and subagencies and 26 laboratories, as well as 33 stakeholders in other organizations.

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1 ORTAs are called a variety of names across agencies, the most common being the Office of Technology Transfer. This report uses the term ORTA to generically represent the office that has the primary responsibility for technology transfer activities.

2 About half of the reports consulted for this study, excluding those used solely to access data, were published before 2000.

The study has two key caveats. First, data were gathered primarily through discussions with laboratory and agency ORTA representatives who represent only one of many stakeholder groups involved in technology transfer. Second, the 6-month timeframe of the study, September 2010 to February 2011, allowed for discussions with representatives of only a small fraction of the nation's laboratories. Though this is the first large-scale study of technology transfer at the federal laboratories in several years, additional research would provide a more complete understanding of the topic. We suggest areas for further study as a part of this report.

B. Outline of Report

The remainder of the report is organized as follows:

- Chapter 2 provides a framework for the study by describing relevant legislation, defining technology transfer and commercialization, and introducing some of the technology transfer mechanisms used at the federal laboratories.
- Chapter 3 summarizes the literature that provided the framework for our discussions with technology transfer staff at agencies and laboratories.
- Chapter 4 describes our methodological approach and limitations of the study.
- Chapter 5 gives a detailed description of the factors that appeared to affect the speed and dissemination of technology from the laboratories to industry for commercialization.
- Chapter 6 describes how laboratories define and measure the success of their technology transfer and commercialization activities.
- Chapter 7 presents technology transfer and commercialization strategies used by the federal laboratories.
- Chapter 8 summarizes the report, presents conclusions, suggests ways to define and measure successful technology transfer, and identifies issues that require further study.

Ancillary information is provided in the following appendixes:

- Appendix A describes the agencies and laboratories interviewed for the study.
- Appendix B summarizes key legislation related to technology transfer from the federal laboratories and describes which legislation applies to which agencies.
- Appendix C describes some of the common mechanisms available to laboratories and agencies for engaging in technology transfer and presents a matrix of mechanisms used by each agency.
- Appendix D presents the discussion guide used to collect data for this study.

- Appendix E describes the laboratory selection methodology.
- Appendix F lists the stakeholders that participated in discussions.
- Appendix G lists the metrics agencies now collect beyond what is reported at the agency level in the annual interagency summary report to the President and Congress on technology transfer.

2. General Framework

This chapter sets the framework for the study. First, it describes federal laboratories and discusses key legislation that formally set in place technology transfer activities at the laboratories. It then examines the definitions of "technology transfer" and "technology transfer that leads to commercialization." These definitions are used throughout the report. Along with those definitions are explanations of the pathways used to transfer technology and the mechanisms employed in these pathways. The chapter ends by distinguishing between the ways that the laboratories transfer technology leading to commercialization and the ways that they transfer technology that does not lead to commercialization.

A. Federal Laboratories

The United States government has founded close to 1,000 federal laboratories since the establishment of the first laboratory in 1846 (CRS 2009a). Approximately one-third of the $103.7 billion in FY 2008 federal research and development (R&D) expenditures (NSF 2010c, 2009) was devoted to intramural R&D performed by federal laboratories (including federally funded research and development centers). Each government agency oversees (but may not manage) its own federal laboratories, but four agencies—the Department of Defense (DOD), Department of Health and Human Services (HHS), National Aeronautics and Space Administration (NASA), and Department of Energy (DOE)—receive the majority of federal R&D intramural dollars (NSF 2009).

The definition of what constitutes a federal laboratory is not straightforward and has been interpreted to include locations such as Yellowstone National Park (Edmonds Institute, et al. v. Babbitt, et al. 2000).[3] The federal laboratories substantially vary from one another in terms of mission, agency, research portfolio, and budget. Some of this diversity can be seen in the brief descriptions of each agency and laboratory interviewed for this study provided in Appendix A. Federal laboratories include both Government-Owned, Government-Operated (GOGO) and Government-Owned, Contractor-Operated (GOCO) laboratories. Contractors who operate laboratories for the government include for-profit companies, nonprofit companies, and universities both singly and in consortia. Increasingly, contractors are using a hybrid of more than one type of organization to

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[3] This case held that Yellowstone National Park qualified as a federal laboratory under the federal Technology Transfer Act of 1986 (which amended Stevenson-Wydler) and was permitted to enter into a CRADA with a bioprospecting firm.

manage and operate federal laboratories. The vast majority of federal laboratories are GOGO, yet all but one of the DOE's laboratories are GOCO. GOGO and GOCO laboratories often have different legislative authorities, and this variation is important in regards to technology transfer.

B. Key Legislation

Beginning in 1980 with the Stevenson-Wydler Technology Innovation Act (P.L. 96-480) (Technology Innovation, Title 15 U.S. Code, §§3701 et seq. (2010)),[4] Congress has periodically passed legislation with the goal of increasing the federal laboratories' beneficial impact on society through technology transfer. The Stevenson-Wydler Act stated that the federal government shall strive, where appropriate, to transfer technology to state and local governments as well as to the private sector (15 U.S.C. §3710(a)(1)). To facilitate the implementation of this mandate, it required that each laboratory with 200 or more technical staff have a technology transfer office, referred to as an Office of Research and Technology Applications (ORTA) (15 U.S.C. §3710(b)). The Bayh-Dole Act of 1980 (P.L. 96-517)[5] allowed federal agencies and GOGO laboratories to issue exclusive licenses to government-held patents. Previously only nonexclusive or open licenses could be granted. Subsequent amendments gave GOCO laboratories the same authority and allowed private companies to obtain an exclusive license for the full life of the government patent (not just five of the seventeen years as it had been previously authorized) (FLC 2009).

The Federal Technology Transfer Act of 1986 (FTTA) (P.L. 99-502) strengthened federal laboratory technology transfer through a mandate that technology transfer be a responsibility of all science and engineering professionals consistent with their mission responsibilities (15 U.S.C. §3710(a)(2)) and the establishment of a principle of royalty sharing for federal inventors at a minimum of 15 percent (15 U.S.C. §3710c(a)(10)(A)(i)). The FTTA created a new mechanism for GOGO laboratories, whereby they could enter into Cooperative Research and Development Agreements (CRADAs) with other federal agencies, state or local governments, industrial organizations, and nonprofit organizations including universities. GOGO laboratories were also allowed to make advance agreements with large and small companies for patent or license rights to inventions resulting from CRADAs. The statute formalized the charter of the Federal Laboratory Consortium for Technology Transfer (FLC) (15 U.S.C. §3710(e)(1)) and required that each agency devote a fraction of their laboratory budget to this organization (15 U.S.C. §3710(e)(6)(A)). GOCO federal laboratories were granted

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4 NASA and USDA had technology transfer authorities before 1980. See Appendix B for a list of legislation affecting technology transfer at the federal laboratories.

5 Formally known as the Patent and Trademark Act Amendments of 1980.

the opportunity to enter into CRADAs and other activities with universities and private industry by the National Competitiveness Technology Transfer Act of 1989 (P.L. 101-189), under similar terms as stated by FTTA.

More recently, Congress has created legislation to guarantee that a CRADA partner will receive a nonexclusive license at minimum (National Technology Transfer and Advancement Act of 1995 (P.L. 104-113), revised the reporting requirement of technology transfer for the federal agencies (Technology Transfer Commercialization Act of 2000 (P.L. 106-404)), and required that the DOE establish a technology transfer coordinator position (Energy Policy Act of 2005 (P.L. 109-58)). Appendix B provides a more extensive list of legislation that affects technology transfer at the federal laboratories.

C. Definitions

1. Technology Transfer

The Stevenson-Wydler Act and subsequent legislation encouraged technology transfer between the federal laboratories, state and local government, and industry, but they did not define which activities constitute technology transfer. There are many facets of technology transfer, so providing a single definition can be difficult (Kremic 2003). The National Science Foundation (NSF) defines technology transfer as the exchange or sharing of knowledge, skills, processes, or technologies across different organizations (NSF 2010a).

> **Definition of Technology**
>
> The word "technology" in "technology transfer" and "technology transfer that leads to commercialization" includes knowledge, skills, processes, and physical technologies. Throughout this report, we use the term "technology" to represent all of these categories.

The FLC definition of technology transfer specific to the federal laboratories incorporates a wide spectrum of agency and laboratory activities.

> Technology transfer is the process by which existing knowledge, facilities, or capabilities developed under federal research and development (R&D) funding are utilized to fulfill public and private need (FLC 2006).

The FLC goes on to explain that technology transfer involves three players: a producer of technology (usually the organization involved in R&D), a user of that technology, and an interface that connects the two, thereby "transferring" the technology from the development center to the user. Typically, the producer's technology transfer office facilitates this interaction (FLC 2006). There may be multiple players beyond these three core players—in particular, as will be further discussed in this report, partnership intermediaries are helping to serve as a boundary-spanning function across the traditional interface of the laboratory ORTA and industry.

2. Technology Transfer that Leads to Commercialization

With such a broad definition, technology transfer as a definition does not depend on the end use of the technology. This report covers activities that accelerate the *commercialization* of federal R&D. Thus, a distinction is made between activities that constitute technology transfer in its broadest sense and technology transfer that leads to commercialization. Such delineation is difficult, as the ultimate use of a technology cannot be determined prior to development.

In a 2003 report on the role that technology transfer and commercialization play in economic development, the EDA defined commercialization as follows.

> Commercialization is the process of transforming new technologies into commercially successful products. The commercialization process includes such efforts as market assessment, product design, manufacturing engineering, management of intellectual property rights, marketing strategy development, raising capital, and worker training. Typically, commercialization is a costly, lengthy process with a highly uncertain outcome. The costs of commercialization can run from between 10 and 100 times the costs of development and demonstration of a new technology. Moreover, success is rare—less than five percent of new technologies are successfully commercialized. Even when successful, technology commercialization does not happen quickly (U.S. Department of Commerce 2003).

While this definition focuses on the transformation of technologies into commercially successful products and does acknowledge the length of time that this can take, it does not paint a picture of the many different players who may be involved in transforming the technology into a commercial product. Furthermore, the commercialization process may also involve further research to determine the feasibility of the technology for commercial application. It is important to keep in mind that the commercialization process can take years or even decades, and laboratories are involved only at the beginning stages of this progression.

For the purposes of this study, the study team adapted a framework for defining technology transfer using a combination of sources that examined government-industry research partnerships. In this framework, laboratory technology transfer may occur along two routes—an indirect pathway and a direct pathway (Ruegg 2000). A third pathway is the creation of networks that may facilitate transfer through one of the other pathways (Ruegg 2000).

Indirect pathways are the dissemination of scientific knowledge through such mechanisms as publications, conferences, and teaching (Ruegg 2000). Such knowledge can ultimately result in commercialized products or processes, but it often takes longer to occur than via the direct pathway. Furthermore, the goal of knowledge dissemination is not tied to commercialization or use by industry (Jaffe 1996).

Direct pathways are the routes used by laboratories and their collaborators to exchange products or processes or further develop technology for specific purposes (Ruegg 2000). Commercialization often takes place as a result of mechanisms in the direct pathway. These direct pathways can be further divided into three types of technology transfer, based on the producer, mechanism, and user of the technology:

- ***Commercial transfer*** is the transfer of technology from a federal laboratory or agency (the producer) to a commercial organization (the user) that can improve technologies by undertaking the technical, business, and manufacturing research to bring them to market. ***Dual use*** is a subset of commercial transfer. It refers to the development of technologies, products, or families of products that have both commercial and federal government applications. The producer is the laboratory or agency, and the user is both the government and industry.
- ***Exporting resources*** occurs when the federal laboratory or agency (the producer) provides expertise to outside organizations including industry, academia, state and local governments, or other federal laboratories or agencies (the user).
- ***Importing resources***, also called technology transition or spin-in, happens when a federal laboratory or agency engages in a cooperative effort that brings technology created by an entity outside the laboratory (the producer) into the agency (the user) to enhance the laboratory or agency’s efforts (FLC 2006).

Network pathways are the activities that build capacity for industry and laboratories to work together. Commercialization of technology may be augmented by activities in the network pathway. These activities involve teaching scientists about commercialization or placing laboratory scientists for a short time in industry so that they can learn about businesses’ needs and perspectives. This pathway includes the conveyance of information through forums and other events that connect scientists or their technologies with potential commercialization partners (Ruegg 2000).

Technology transfer incorporates all three pathways, and commercialization may occur as the result of technologies transferred in any of these ways. However, the direct and network pathways, because of their specific concentration on transfer between the laboratory and industry, are generally considered to most directly lead to commercialization. This report focuses on the direct and network pathways of technology transfer.

The ways in which laboratories accomplish technology transfer are called “technology transfer mechanisms.” Some of these mechanisms require legal authorities while others are informal and do not typically involve legal authorization. Table 1 lists some examples of the mechanisms used in each pathway.

Table 1. Technology Transfer Mechanisms by Type of Pathway

Indirect Pathway Mechanisms	Direct Pathway Mechanisms	Network Pathway Mechanisms
Conference Papers	*Invention Protection*	Commercialization Assistance Program
Education Partnership Agreements	Invention disclosures	Entrepreneurship-in-residence programs
Field Days	Patent applications	Entrepreneurship Training
Intramural Research Training Awards	Issued patents	Mentor-Protégé Program
Publications	*Transfer of Property*	Personnel Exchange Agreements
Seminars	Material Transfer Agreements	Partnership Intermediary Agreements
Teaching	Patent licenses	Venture Capital Forums
Workshops	Inter-Institutional Agreements	
	Collaborative Research Agreements	
	Cooperative Research and Development Agreements	
	Space Act Agreements	
	Collaboration Agreements (Non-CRADA)	
	Resource Use Agreements	
	Commercial Test Agreements	
	Test Service Agreements	
	User Facility Agreements	
	Work for Others	

Source: Adapted from Ruegg (2000) and FLC (2009).

Notes: In this report, we use the terms "technology transfer" to mean indirect, direct, and network pathways and "technology transfer that leads to commercialization" to mean direct and network pathways.

D. Selected Technology Transfer Mechanisms

Technology transfer legislation affecting all agencies and agency-specific statutes provide legal mechanisms for the federal laboratories to engage in technology transfer activities. These mechanisms vary by laboratory. Mechanisms can be categorized into four groups: invention protection, direct transfer of property, collaborative research agreements, and resource use agreements. Some of the more common technology transfer mechanisms are defined as follows:

- *Patent licenses* allow the licensee to exploit the intellectual property, but does not transfer the title or ownership of the patent.
- *Cooperative Research and Development Agreements (CRADAs)* are formal research contracts between federal laboratories and nonfederal entities to work

together to advance technologies toward applications of interest to the nonfederal entity and simultaneously toward meeting agency missions.

- *User Facility Agreements (UFAs)* allow outside parties access to the research equipment and facilities of federal laboratories.
- *Work-for-Others (WFO) agreements* are contracts for performance of research, but the research or technical assistance is wholly performed by the federal laboratory and fully funded by the partner entity, which can be industry or another agency or laboratory.
- *Partnership Intermediary Agreements (PIAs)* are between nonprofit organizations (partnership intermediaries) and federal laboratories to facilitate technology transfer (15 U.S.C. §3715).[6]

Appendix C lists mechanisms and provides a matrix describing the legal authorities available to agencies.

E. Federal Laboratories and Technology Transfer

The Stevenson-Wydler Act mandated that federal agencies and laboratories engage in technology transfer consistent with their mission. This mission plays a large part in determining the technology transfer pathways used by each laboratory. All laboratories engage in each pathway in different relative frequencies. For example, a basic research laboratory may more commonly transfer its technology by publishing results in the academic literature. However, an invention that has commercial potential and requires protection via a patent can be transferred to industry through a patent license agreement.

1. Examples of Technology Transfer that May Lead to Commercialization

In many cases, a federal laboratory's technology transfer activities function through the direct or network pathway, and, thus, directly support commercialization. This occurs most often when the achievement of the laboratory's mission necessitates commercialization. For example, the development of drugs and vaccines requires both investment in basic research by the federal laboratories within the National Institutes of Health (NIH) and a lengthy research and development process to create a drug or vaccine. Industry undertakes this process and commercializes the technology, thereby ensuring that NIH accomplishes its mission.

Activities other than licensing of a technology created at a laboratory are considered to be in the direct pathway. For example, a laboratory may support a company through a

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[6] Partnership intermediaries provide services to federal laboratories, including marketing assessments, business plan development assistance, identification of funding sources, access to facilities, equipment and research expertise through formal agreements, and assistance in technology matching.

collaborative research project that assists the company in either improving on an existing technology or developing a wholly new product or process. The federal laboratories offer not only user facilities but also unique resources, including scientific and engineering expertise. Industry usage of these capabilities can directly supports commercialization.

2. Technology Transfer that Does not Lead Directly to Commercialization

Although this report focuses on technology transfer that leads to commercialization, the federal laboratories are also responsible for technology transfer that leads to indirect economic and social returns such as the creation of knowledge. The laboratories contribute to society by providing critical research in areas that universities and the private sector may not perform.

Federal laboratories provide services to other laboratories and agencies, state and local governments, and other governments around the world. Many state agencies depend on the information, products, and capabilities of the Department of the Interior's U.S. Geological Survey. The National Oceanic and Atmospheric Administration's Earth Systems Research Laboratory provides instrumentation to the Department of Energy for climate change research. Laboratories also transfer the results of their research to other laboratories or entities within the same agency. Results from basic research performed by the Naval Research Laboratory are often used by applied research laboratories within the Department of Defense. These activities may lead to commercialization of a product further downstream, yet the transfer of technology at the point it leaves the laboratory does not have that commercial focus.

The laboratories further disseminate their research through academic publications and information services, and they educate thousands of students and researchers in all stages of their career. The U.S. Army's Armament Research, Development and Engineering Center uses technology transfer tools to train mechanical and electrical engineers in armaments. The National Institute of Standards and Technology in the Department of Commerce supports many guest researchers from industry and academia.

F. Summary

The federal laboratories receive about a third of federal R&D spending, and legislation to support the transfer of technologies developed at these laboratories has been in place for over 30 years. The definition of technology transfer is broad and encompasses a variety of activities. In this report, a distinction is made between technology transfer in general and technology transfer that leads to commercialization. Three pathways for general technology transfer are described: indirect, direct, and network. Although this report focuses on technology transfer that leads to commercialization, the laboratories do a number of important technology transfer activities that do not directly lead to commercialization. Focusing solely on the impact of the technology transfer that leads to commercialization misses the indirect pathway of technology transfer, a conduit that leads to important economic and societal returns.

3. Literature Review

This chapter provides an overview of our literature review and discusses the barriers to technology transfer we identified. It ends with a statement of the limitations of applying the reviewed literature to current technology transfer activities. Although we differentiate between technology transfer and technology transfer that leads to commercialization in this study, the literature does not make this distinction.

A. Approach

Our literature review included both peer-reviewed academic publications and texts published by government and other nonprofit sources. It covers the policies, models, metrics, barriers, and strategies related to technology transfer within the context of the federal laboratories. Although technology transfer activities at federal agencies and laboratories have matured over time, our literature review focused on the challenges and barriers that remain.

While much has been written on technology transfer from universities, we generally excluded such literature from the review. This exclusion was due only to the limited time for this study; according to stakeholders, there are likely many parallels to be drawn between the federal laboratories and universities.

B. Barriers to Technology Transfer

In particular, the literature review highlighted barriers related to technology transfer from the federal laboratories.

- Technology varies across laboratories due to the diversity and scope of the laboratories' missions.
- Technology transfer often does not have sufficient agency and laboratory support.
- Researchers may lack sufficient expertise for commercialization.
- Laboratories may not reach out to industry.
- Laboratories often do understand the market for their technologies.
- Government requirements may hinder interactions with the industry.
- Businesses report that negotiation times are too lengthy.
- Congress has not appropriated funds to support technology transfer.

- Laboratories often lack technology funding to further develop or mature the technology to ready it for adoption by the private sector.

The following sections highlight the barriers identified in the literature review.

1. Technology Transfer Varies Across Laboratories Due to the Diversity and Scope of the Laboratories' Missions

The literature review found that the technology transfer mandate did not necessarily align with the primary mission of the laboratories. Multiple reports in the 1990s discussed the importance of technology transfer in fitting in with laboratory capabilities (Spivey, Munson, and Flannery 1994; Bozeman and Crow 1991). Even when a laboratory was conducting research related to product applications, it was likely to be primarily related to agency needs, not to those of industry (Papadakis 1995).

2. Agency and Laboratory Support for Technology Transfer

During the 1990s, reports indicated a lack of support for technology transfer programs from personnel at agencies and laboratories. A U.S. Government Accountability Office (GAO) evaluation of the technology transfer programs within the Department of Energy (DOE) laboratories highlighted the lack of a high-level, effective advocate within the laboratories as well as the need for an institutional commitment to technology partnerships as a way to accomplish agency missions (GAO 1995). A study of laboratories in the FLC's Mid-Continent Region found that lack of agency support was a major barrier to commercialization activities (Chapman 1997).

3. Researchers' Ability to Perform Technology Transfer

Studies from the 1990s and 2000s noted that researchers might be a barrier to transferring technology. For example, federal scientists can be unaware of the commercial potential of their inventions (Greiner and Franza 2003). Public sector researchers often lack training to deal with the business issues that come up in commercialization projects (Markusen and Oden 1996). Agency and laboratory technology transfer officials reported that "governmental employees do not typically possess a natural entrepreneurial spirit" (Riggins and London 2009). Researchers have also hypothesized that cultural barriers between researchers and technology transfer personnel affect technology transfer from NASA laboratories (Toregas 2004; Bush 1996).

4. Outreach from Laboratories to Industry

The literature also stated that many laboratories lack the ability to publicize their research and development capabilities to industries, and companies can only license and commercialize technology from the federal laboratories if they are aware that they exist.

Though much of the literature is from the 1990s, a Congressional Research Service (CRS) report from 2009 asserted that industry's unfamiliarity with available technologies causes a barrier to technology transfer (CRS 2009c). An older case study analyzed five technologies relating to the environment developed by the U.S. Air Force. Barriers to technology adoption included difficulty in demonstrating these technologies to potential users (Brown 1997). Furthermore, laboratories lacked outreach activities that identify industrial collaborators due to low prioritization of technology transfer (Chapman 1997).

5. Market Analyses on Laboratory Technologies

The earlier literature indicated that federal laboratories' Offices of Research and Technology Applications (ORTAs) did not employ market research tools, long used in the private sector to understand market pull (Robertson and Weijo 1998). Authors argued that laboratories should implement techniques such as market analyses, competitive analyses, market target determination, and adoption strategies to increase the applicability of their technologies to the market (Piper and Naghshpour 1996). More recent literature demonstrates that some federal laboratories do have strategies to market technologies. See, for example, a study by Ramakrishnan, Chen, and Balakrishnan (2005) on the market strategies used by the National Institutes of Health (NIH) Office of Technology Transfer.

6. Government Requirements Hinder Interactions with Industry

Because federal laboratories are government institutions, they must comply with rules and procedures that may inadvertently inhibit or slow the technology transfer process (Jaffe 2000; Markusen and Oden 1996). The literature review identified several rules reported to hinder technology transfer from the laboratories, including fairness of opportunity, conflict of interest, and other statutory requirements.

Prior to transferring public property into the hands of one or a few private parties, federal laboratories must attempt to publicize the opportunity to ensure fairness of opportunity to all businesses. For example, laboratories must publish their intent to grant an exclusive or partially exclusive license[7] in the Federal Register for 15 days to ensure that there are no other interested parties (Technology Transfer Commercialization Act of 2000).[8] Conflict-of-interest rules ensure that public employees do not unfairly benefit from federally funded inventions. Compliance with fairness-of-opportunity and conflict-of-interest rules can be challenging, and criticism over misuse of rules has led to reduction of technology transfer activities. For example, a decline in patenting during the

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[7] Licenses for CRADA partners are exempt from this condition.

[8] The Technology Transfer Commercialization Act (TTCA) of 2000 (P.L. 106-404) reduced the timeframe from a 3-month publication in the Federal Register plus a 60-day notice of intent to license to a 15-day notice.

mid-1990s was found by one author to result from congressional criticism of violations of fairness-of-opportunity and conflict-of-interest regulations (Jaffe 2000).

Other statutory requirements can inhibit technology transfer, including the necessity for industrial partners to conduct manufacturing in the United States (CRS 2009b). A partnering firm must establish U.S. manufacturing facilities, sign a toll manufacturing agreement with a U.S. manufacturer, or provide a plan for how the venture will benefit the U.S. economy. Increasingly, start-up companies locate their manufacturing offshore to reduce costs, and GAO reports that the desire of companies to do so poses a large barrier to licensing laboratories' technologies (GAO 2002).

7. Length of Negotiation Times

The literature review suggested that company partners are critical of the length of time and complexity of government administrative arrangements necessary to form a CRADA (Rogers et al. 1998). Private industrial collaborators cite slow-moving bureaucracy and excessive rules and regulation as some of the top deal breakers of collaborative agreements with federal laboratories, and private firms rate their government collaborators poorly on time taken to complete core organizational activities (Bozeman and Crow 1991). Of course, such complaints are from the perspectives of companies and businesses rather than the government.

Roadblocks related to the allocation of intellectual property may also be encountered during the negotiation process (Bodde 1993). Each agency uses different rather than standardized legal documents (Riggins and London 2009), making it difficult for businesses to work across agencies. Technology transfer rules related to intellectual property and royalties are typically based on the institutional status of the partners, such as nonprofit or business, and assume only one type of partner is involved in a technology transfer agreement. This situation can present challenges when there are multiple disparate parties engaged in a joint research project.

8. Technology Transfer Is an Underfunded Mandate

The literature emphasized that technology transfer is an underfunded legislative mandate, which may adversely affect technology transfer activities. As Riggins and London (2009) state, "An agency's [technology transfer] program is only as effective as the resources devoted by the agency." Furthermore, in situations of scarce resources, technology transfer's underfunded nature can lead to active opposition to it, as technology transfer funnels away critical resources that could be used for mission-based research (Spivey, Munson, and Flannery 1994).

9. Technology Maturation Funding at Laboratories

Another common theme in the literature was a lack of funding to ready the technology for adoption by the industry. A recent CRS report indicated that a significant amount of funding, as well as time and energy, is needed to facilitate the adoption of the new technology by commercial entities (CRS 2009c). For example, much of the research developed at NIH is at a stage that requires a large investment by industrial partners (Riggins and London 2009). Jensen and Thursby point out that many university-developed technologies are so underdeveloped that they are doomed to remain in the laboratory unless incentives are added to induce ongoing collaboration between the inventors and the entrepreneurs seeking to take them to market (2001).

C. Applicability to the Current Study

The literature review identified nine main barriers to technology transfer; however, the literature review had two major limitations.

First, about half of the literature reviewed for this study was published in the 1990s, making it potentially unreliable to assess the current state of technology transfer at the federal laboratories. The world has changed considerably over the past twenty years. For example, increased globalization may affect the processes through which technologies are commercialized. Shifts in research priorities and new innovations may affect the nature of interactions and partnerships between the federal laboratories and companies. Furthermore, a rapidly evolving information and communication technology landscape may affect the visibility of the federal laboratories as well as their technologies and resources. The current study identified new and updated known barriers to technology transfer that leads to commercialization. We examine these in Chapter 5.

Second, only a few studies examined the federal laboratories as a whole. The majority of academic literature and government reports focused only on laboratories within a single agency. Most of the available literature deals with a subset of agency laboratories, primarily those from the DOE, NASA, DOD, and U.S. Department of Agriculture (USDA). The current study includes laboratories across those agencies and many more.

D. Summary

The literature highlights nine barriers to transferring technology out of the federal laboratories. Technology transfer varies across laboratories due to the diversity and scope of the laboratories' missions. Technology transfer may not have sufficient agency and laboratory support. Researchers may lack sufficient expertise for commercialization. Laboratories may not reach out to industry, and they may not understand the market for their technologies. Government requirements may hinder interactions with the industry.

Businesses report that negotiation times are too lengthy. Congress did not set funding levels for laboratories to do technology transfer. Laboratories may lack technology maturation funding. However, much of the literature on these barriers is dated and focuses on a small subset of the laboratories. As the next chapter shows, while the same barriers exist, the strategies for technology transfer at the federal laboratories have evolved.

4. Methodological Approach

This chapter describes the formation of the data collection instrument and the study's data collection approach. The chapter ends with an explanation of limitations of the study, the reliance on interviews with Office of Research and Technology Applications (ORTA) staff and the limited number of discussions.

A. Discussion Guide

The technology transfer strategies and barriers discussed in the literature review directly aided the development of agency- and laboratory-level discussion guides. Specifically, the data collection instrument included questions about the barriers and strategies that were identified in the literature review. In addition to asking questions relating to barriers and strategies, the discussion guides also explored general laboratory characteristics, laboratory mission, implementation of technology transfer that leads to commercialization at the laboratory, interactions with industry, partnerships with other organizations, measures of technology transfer that leads to commercialization, and laboratory culture. See Appendix D for the full discussion guide.

B. Data Collection

The study's primary data source was semi-structured discussions with technology transfer representatives from laboratories and agencies, representatives from organizations designed to work with the laboratories and industry (known as partnership intermediaries), and other stakeholders. Separate discussion guides were developed for laboratories and agencies, and these instruments were based on findings in the background report and initial talks with stakeholders. We tested the guides during preliminary conversations and made necessary modifications. A guide was also developed for dialogue with partnership intermediaries.

We conducted these conversations over a 6-month period between September 2010 and February 2011. In total, we talked to 26 laboratory ORTA representatives and 13 agency and subagency technology transfer coordinators. See Table 2 for participating agencies and Table 3 for participating laboratories. Selected laboratories represented the overall population of laboratories on most characteristics, including parent agency, contractor type, and geographic location. See Appendix E for a description of the laboratory selection strategy. In addition to these main interviewees, we interviewed 33 other stakeholders, including 7 partnership intermediaries. See Appendix F for a full description of these discussions.

Table 2. Agency and Subagency Technology Transfer Offices

Abbreviation	Agency/Subagency	Discussion Date
DHS	Department of Homeland Security	Dec. 1, 2010
DOC–NOAA	Department of Commerce, National Oceanic and Atmospheric Administration	Dec. 9, 2010
DOD	Department of Defense	Nov. 4, 2010
DOD–ONR	Department of Defense, Office of Naval Research	Nov. 29, 2010
DOE	Department of Energy	Oct. 25, 2010
DOI–USGS	Department of the Interior, U.S. Geological Survey	Nov. 17, 2010
DOT–FRA	Department of Transportation, Federal Railroad Administration	Dec. 20, 2010
EPA	Environmental Protection Agency	Nov. 16, 2010
HHS–FDA	Department of Health and Human Services, Food and Drug Administration	Dec. 16, 2010
HHS–NIH	Department of Health and Human Services, National Institutes of Health	Nov. 17, 2010
NASA	National Aeronautics and Space Administration	Nov. 15, 2010
USDA	U.S. Department of Agriculture	Nov. 5, 2010
VA	Department of Veterans Affairs	Nov. 9, 2010

Table 3. Laboratory Technology Transfer Offices

Agency	Type	Laboratory	Discussion Date
DOC	GOGO	National Institute of Standards and Technology	Nov. 30, 2010
DOC	GOGO	NOAA Earth Systems Research Laboratory–Colorado	Sept. 27, 2010
DOC	GOGO	NOAA Hollings Marine Laboratory	Nov. 18, 2010
DOC	GOGO	NOAA Coastal Environmental Health and Biomolecular Research	Nov. 18, 2010
DOD	GOGO	Air Force Research Laboratory	Dec. 14, 2010
DOD	GOGO	Army Armament Research, Development and Engineering Center	Nov. 18, 2010
DOD	GOGO	Army Medical Research and Materiel Command	Dec. 16, 2010
DOD	GOGO	Naval Surface Warfare Center Crane Division	Nov. 23, 2010
DOE	GOCO	Lawrence Berkeley National Laboratory	Dec. 15, 2010
DOE	GOCO	Lawrence Livermore National Laboratory	Dec. 8, 2010
DOE	GOCO	Los Alamos National Laboratory	Nov. 4, 2010
DOE	GOCO	National Renewable Energy Laboratory	Sept. 27, 2010
DOE	GOCO	Oak Ridge National Laboratory	Dec. 7, 2010
DOE	GOCO	Pacific Northwest National Laboratory	Nov. 29, 2010
DOE	GOCO	Sandia National Laboratories	Nov. 5, 2010
DOE	GOCO	Savannah River National Laboratory	Dec. 2, 2010
DOT	GOGO	Federal Aviation Administration—William J. Hughes Technical Center	Dec. 22, 1010
DOT	GOGO–fee for service	RITA John A. Volpe National Transportation Systems Center	Dec.13, 2010
HHS	GOGO	National Cancer Institute	Dec. 9, 2010
HHS	GOGO	National Heart, Lung and Blood Institute	Dec. 6, 2010
HHS	GOGO	National Institute of Allergy and Infectious Diseases	Dec. 16, 2010
HHS	GOGO	National Institute of Diabetes and Digestive and Kidney Diseases	Dec. 10, 2010
HHS	GOGO	National Institute of Neurological Disorders and Stroke	Dec. 9, 2010
NASA	GOGO	Goddard Space Flight Center	Dec. 21, 2010
NASA	GOCO	Jet Propulsion Laboratory	Dec. 15, 2010
USDA	GOGO	Beltsville Agricultural Research Center	Dec. 17, 2010

Field notes were written shortly after each discussion. The purposes of the field notes were to synthesize topics of conversation and provide written documentation on each dialogue. As discussions progressed, we iteratively coded group responses around barriers to technology transfer that leads to commercialization and strategies employed to overcome such barriers. Ultimately, topics discussed in conversations were organized under the categories reflected in the factors and measures and metrics chapters of this report (Chapters 5 and 6).

C. Study Limitations

Despite its methodical approach, this study has limitations. First, STPI primarily gathered data through discussions with agency-level technology transfer personnel and laboratory ORTA representatives. Thus, findings are derived almost exclusively from the perspective of the technology transfer office and ORTA staff. Discussions were not held with agency and laboratory leadership, which would have shed light on the alignment of mission with the technology transfer activities that lead to commercialization. Although STPI conducted a small number of stakeholder conversations to glean the researcher perspective, we did not conduct a series of systematic discussions with laboratory researchers, a population that this study’s interviewees identified as crucial to technology transfer. This topic would further profit from a study focused on commercialization activities from the perspectives of researchers as well as laboratory directors and agency leadership. Second, the industry perspective in this study is limited to conversations with stakeholders and partnership intermediaries (see Appendix F for lists of these latter two groups).

D. Summary

The primary data for this systematic study of technology transfer and commercialization were from discussions with 26 laboratory ORTA representatives and 13 agency and subagency technology transfer coordinators. Iterative coding from discussion responses were organized into factors (see Chapter 5) and metrics (see Chapter 6). Conversations were limited to technology transfer representatives, representatives from partnership intermediaries, and other stakeholders in the technology transfer community.

5. Factors Affecting Technology Transfer that Leads to Commercialization

Based on discussions with personnel from agency-level technology transfer offices and laboratory Offices of Research and Technology Applications (ORTAs), partnership intermediaries, and other stakeholders, STPI corroborated, refuted, and expanded upon findings that emerged from the earlier review of the literature. This chapter synthesizes the results and groups observations into nine high-level factors that appear to affect the speed and extent of dissemination of technology transfer from a federal laboratory, as well as the overall ease of laboratory-industry interactions. These factors are:

1. *Laboratory mission.* Technology transfer varies across laboratories due to the diversity and scope of their missions. Some laboratories are more inclined towards technology transfer that leads to commercialization because it is in the interest of achieving the mission of the laboratory, agency, or subagency.
2. *Laboratory management.* Differences between Government-Owned, Government-Operated (GOGO) and Government-Owned, Contractor-Operated (GOCO) laboratories can affect technology transfer and commercialization activities. GOCO laboratory leadership is often explicitly tasked to perform technology transfer and commercialization, while GOGO laboratories must comply with certain government regulations that do not affect GOCOs.
3. *Congressional support and oversight*. Despite congressional support for technology transfer at the federal laboratories, congressional action and oversight can have the unintended consequence of encouraging a risk-averse culture towards technology transfer. Furthermore, technology transfer activities can be undermined when congressional priorities shift, as technology transfer requires long-term support.
4. *Agency leadership and laboratory director support*. Support from agency leadership and laboratory directors can have a marked effect on technology transfer and commercialization activities. For example, laboratory directors who support technology transfer may provide resources, flexibility, and creative license to their ORTAs. Those ORTAs who are not supported by their laboratory leadership can be severely constrained.
5. *Organization and coordination of technology transfer and commercialization activities*. The centralization/decentralization of technology transfer functions at

the agency and laboratory levels affects the speed of implementation of technology transfer actions, the consistency of policies across laboratories within an agency, and the ability to share best practices. The location of ORTAs within an agency and laboratory can affect the visibility of technology transfer.

6. *Offices of Research and Technology Applications*. Operations that seem to affect technology transfer and commercialization include the responsibilities of the office; the science, technology, and business expertise of the staff; the processes of the office; and the legal authorities available to the laboratory and how they are interpreted by ORTA staff.
7. *Researchers.* Laboratory researchers, whose participation in technology transfer and commercialization processes varies across laboratories, may lack the knowledge, ability, and incentives necessary to undertake the research, administration, and business development involved in successful technology transfer.
8. *Government-industry interactions.* Federal laboratories are not visible and accessible to industry, and certain regulations make it difficult for federal laboratories and industry to interact. According to partnership intermediaries, groups designed to broker partnerships between the laboratories and industry, industry is largely unaware of opportunities to collaborate with the federal laboratories.
9. *Resources.* Resources devoted to technology transfer and commercialization vary across laboratories and agencies. Further, the extent to which the agencies and laboratories leverage federal, state, and local programs that support technology-based economic development may also affect technology transfer and commercialization.

The factors are not mutually exclusive and are highly influenced by one another. This chapter describes these factors, details how they can positively or negatively affect technology transfer that leads to commercialization, and provides select examples heard from various laboratories' and agencies' ORTA representatives.

A. Laboratory Mission

The Stevenson-Wydler Act stated, "technology transfer, consistent with mission responsibilities, is a responsibility of each laboratory science and engineering professional" (15 U.S.C. §3710(a)(2)). However, the missions of the federal laboratories vary. Throughout the course of data collection, it was clear that a wide variation in mission led certain laboratories to be more or less suited to technology transfer that leads to commercialization. The following section discusses how agency and subagency focus, laboratory research, and the industries related to this research might affect the ability of a laboratory to transfer technology focused on "commercializable" applications.

1. Agency and Subagency Focus

The laboratories receive their missions from their parent agencies, which are diverse with respect to how well aligned they are with technology transfer and commercialization. For example, some agencies' missions explicitly state the importance of transitioning technologies to industry, while others do not. Consider the following two examples.

The U.S. Department of Agriculture (USDA) contains the Agricultural Research Service (ARS), a group of over 100 research sites located across the United States, most of which have relatively small staffs and budgets. (The total ARS intramural R&D budget was $1.45 billion in FY 2008). According to the USDA-ARS website (http://www.ars.usda.gov/main/main.htm), the service conducts both basic and applied agricultural research. USDA-ARS's mission statement identifies technology transfer as one of the organization's missions (http://www.ars.usda.gov/aboutus/aboutus.htm):

> ARS conducts research to develop and transfer solutions to agricultural problems of high national priority and provide information access and dissemination to ensure high-quality, safe food, and other agricultural products, assess the nutritional needs of Americans, sustain a competitive agricultural economy, enhance the natural resource base and the environment, and provide economic opportunities for rural citizens, communities, and society as a whole.

Located in the Department of the Interior (DOI), the U.S. Geological Survey (USGS) had an intramural R&D budget of $490 million in FY 2008. Although the functions mandated to accomplish the USGS mission (http://www.usgs.gov/aboutusgs/) include the publication and dissemination of information, achieving the mission does not require commercialization of USGS-developed technologies.

2. Nature of Research and Associated Industries

The nature of the research mandated by the mission of each federal laboratory also can affect its ability to transfer technology that leads to commercialization. First, some laboratories produce technologies that are closer to basic research and, thus, further away from being ready for market. Second, the type of research mandated by a mission can affect the applicability of inventions to various industries. Furthermore, certain types of research licensed to specific industries may be more or less profitable, which may affect the incentives for patenting the technology. Together the type of research defined by a laboratory's mission will affect the transfer of technologies to be commercialized by industries.

Some laboratories produce technologies that are better suited for commercialization because they do more applied research. The commercialization process occurs at the end of a long spectrum of research and development. According to the Air Force Research Laboratory (AFRL), the Technology Readiness Level (TRL) of the research plays into whether or not a technology will be commercialized. As several partnership intermediaries stated, research further along the continuum to commercialization is more likely to be licensed by companies or funded by venture capital firms.

The field of research associated with specific laboratories can also play into its ability to transfer technology that leads to commercialization. Some laboratory ORTA staff mentioned that some of their classified research results in inventions that cannot be commercialized.

The type of industry with which a laboratory is likely to partner can also affect the patenting and licensing processes at laboratories. Like the laboratories themselves, "industry" is not a single entity and displays a wide diversity of interests, foci, and functions. An industry sector can be a robust and well-established area, or it could be an emerging sector. The individual company with which a laboratory partners can be a large company, a small company designed to stay small, or a start-up hoping to revolutionize an industry. There is no one-to-one match between a laboratory and the type of industry with which it works, but there are differences in the dynamics that exist in laboratory-industry partnerships depending on these factors.

Laboratories have diverse missions, which are shaped by the agencies and subagencies under which they are located. These diverse missions lead to differences in the types of research performed and the expected associated industries with which a laboratory might collaborate. Thus, laboratory mission can affect the ability for laboratories to transfer technology that leads to commercialization.

B. Laboratory Management

Broadly speaking, there are two types of laboratory management and operation: (1) GOCO laboratories, and (2) GOGO laboratories. Each type operates under different regulations and guidelines.

GOCO laboratory leadership is often explicitly tasked to perform technology transfer and commercialization as an integral part of its mission. When the contracts for the Department of Energy (DOE) GOCO laboratories were competed, a commercialization goal was placed in the management plan of each. For example, the FY 2011 Lawrence Berkeley National Laboratory (LBNL) Performance Evaluation and Measurement Plan requires their laboratory operator to "demonstrate effective transfer of technology and commercialization of intellectual assets" (FY 2011 Performance Evaluation and Measurement Plan (PEMP), Attachment J-2, Appendix B). DOE appraises these management plans each year, and the operators of DOE GOCO laboratories are judged partially on their technology transfer activities that lead to commercialization. (FY 2011 Performance Evaluation and Measurement Plan (PEMP), Attachment J-2, Appendix B).

Battelle Memorial Institute manages or co-manages six GOCO laboratories for DOE and one for the Department of Homeland Security (DHS).[21] Like all DOE GOCO laboratories, technology transfer and commercialization is an explicit part of the focus of Battelle Memorial Institute's laboratories. However, according to one interviewee, Battelle has a uniquely commercialization-centric approach to technology transfer, defining it by the amount of technology that helps expand economic opportunity for U.S. citizens. The laboratories operated by Battelle have a specific working group to exchange best practices.

Universities vs. Federal Labs

The federal government passed Bayh-Dole and Stevenson-Wydler in the same year. However, it was not until Federal Technology Transfer Act of 1986 that federal laboratories had similar authorities as universities. Universities and laboratories are different in that university researchers often have more flexibility than federal government employees when it comes to activities with industry, such as beginning spin-outs and taking equity in start-ups. Also, for example, university extramural researchers funded by the NIH can consult one day per week and must obtain outside funding for their programs, unlike most federal laboratories.

In addition to the GOCO laboratories' explicit focus on commercialization, these laboratories' employees are not federal employees. GOGO employees must comply with government-specific rules such as fairness of opportunity, federal acquisition regulations, and heightened conflict of interest that may slow or impede dealing or partnering with industry. They are also subject to prohibitions on activities commonly undertaken by their GOCO and university laboratory counterparts, such as copyrighting, consulting with industry, and participating in start-ups based on technology developed at the laboratory.

Some GOGO employees have dual-appointments with universities, which can provide greater flexibility for researchers to conduct technology transfer activities. The National Oceanic and Atmospheric Administration (NOAA) and the University of Oklahoma jointly run the Severe Storms Laboratory. The laboratory has taken advantage of its involvement with the university to secure copyright protection of their software. Similarly, 90 to 95 percent of U.S. Department of Veterans Affairs (VA) hospital researchers are affiliated with university hospitals, so the majority of technology transfer practices at these centers are enmeshed with the technology transfer offices of

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[21] Battelle manages or co-manages Brookhaven National Laboratory, Idaho National Laboratory, Lawrence Livermore National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory for DOE and the National Biodefense Analysis and Countermeasures Center of DHS.

universities. For the most part, the VA allows universities to undergo the patenting and licensing of technology developed by these dual-appointed employees, in part due to the flexibility afforded to the universities in doing technology transfer.

Laboratory management type (GOCO versus GOGO) affects approaches to, ability to engage in, and importance placed on technology transfer and commercialization activities.

C. Congressional Support and Oversight

Interviewees, especially those who had a long history of involvement in technology transfer at the federal laboratories, stated that congressional support for and oversight of technology transfer affects the activities and outputs of the federal laboratories. Beyond passing technology transfer legislation, congressional committees are responsible for setting agency and laboratory budgets, which sometimes can provide specific support for technology transfer activities. For example, for a period in the mid-1990s, Congress provided DOE with funds to support researchers in CRADA participation, leading to a rise in the number of CRADAs at DOE laboratories. Stakeholders stated that the program was halted after an expose in the *Philadelphia Inquirer* derided the practice as "corporate welfare" (Gaul and Stranahan 1995). During an assessment of CRADA operations at the DOE laboratories, the Government Accountability Office (GAO) reported that the elimination of this and other funding programs had resulted in a 40-percent decrease in the number of DOE CRADAs between 1996 and 2001. GAO stated that many industry partners cancelled CRADAs when they learned that they would have to cover the total costs for the collaborative research effort (GAO 2002).

Congressional action can also affect agency mission priorities, which, as stated before, has a significant effect on how the laboratories approach technology transfer that leads to commercialization. The National Aeronautics and Space Administration (NASA) mission has shifted several times over the last three decades, sometimes due to congressional priorities. Such a shift has affected technology transfer that leads to commercialization at their ORTAs (NAPA 2004). Interviewees stated that successful technology transfer requires a long-term approach and this approach can be undermined when priorities change.

Congress also can convene hearings to investigate any perceived wrongdoings related to technology transfer that leads to commercialization. Interviewees reported that such investigations can have a chilling effect. In 2003, the House Energy and Commerce Committee raised concerns about National Institutes of Health (NIH) employees receiving payments for lectures given on behalf of a company. This concern was followed by a 2004 Senate Appropriations Subcommittee on Labor, Health and Human Services, and Education hearing entitled "Avoiding Conflicts of Interest at NIH" (Zerhouni 2004). To address the issue, NIH revised its conflict-of-interest policies.

Several interviewees stated that the policies are now overly burdensome and prohibit ordinary interactions between NIH researchers and industry.

Congressional oversight can affect the technology transfer processes and outputs at laboratories, in particular when congressional support and priorities change.

D. Agency Leadership and Laboratory Director Support

Discussion responses corroborated reports from the literature that agency and laboratory director support facilitates technology commercialization (Chapman 1997; Link, Siegel, and Van Fleet 2011). According to interviewees, certain laboratory directors, particularly those at GOCO laboratories, have made the commercialization of technology a priority at their institutions. For example, one GOCO interviewee reported that a laboratory director told the laboratory leadership team that technology transfer is everybody's responsibility, which served to highlight the importance of technology transfer and partnerships to all laboratory staff. A few GOGO ORTAs also asserted that they received high levels of support from their laboratory directors or agency leadership. At one laboratory, the ORTA representative stated that the laboratory leadership is "enamored" with technology transfer. Furthermore, some laboratory directors regularly keep their ORTA director abreast of the strategic planning activities of the laboratory.

Other laboratory and agency technology transfer coordinators felt that they received little to no support from their laboratory directors or agency leadership, respectively. More often, ORTA interviewees felt that the laboratory director did not feel strongly (either positively or negatively) about technology transfer that leads to commercialization. In these cases, interviewees stated that they felt neither incentivized nor penalized based on the activities and performance of their office.

The level of support from the laboratory director appears to affect how technology transfer operates at the laboratory. Interviewees stated that high levels of support from the laboratory director can be instrumental in allowing ORTAs to perform their duties to the maximum possible extent. If the laboratory director is a champion of technology transfer, the ORTA personnel reported they are often given resources, flexibility, and the ability to be creative in performing their duties to transfer technologies to industry. One agency-level technology transfer employee stated, "If the director of a center is focused on TT [technology transfer], then the center will also focus more on TT. If leadership at the agency is focused and supportive of TT, then this attitude will trickle down to others in the agency." Another ORTA representative reported that the laboratory director is involved in programs to incentivize researchers and the ORTA reports directly to the laboratory director's office.

Conversely, if a laboratory director does not support technology transfer that leads to commercialization activities, ORTA activities can be severely constrained. For example, the ORTA representative at one laboratory stated that a drastic drop in patents and licenses was due in large part to the director being unsupportive of those activities. At another laboratory, the interviewee stated the new laboratory director had said that the laboratory's focus would solely be on the science and not on transferring technology. The laboratory director can also change the focus of an ORTA, choosing to prioritize certain types of technology transfer activities over others. At one laboratory, the ORTA representative reported that the current laboratory director wished to focus on research partnerships as opposed to patenting and licensing, leading to a drop in licenses.

Interviewees reported that at some of the laboratories, an enthusiastic and motivated person within the ORTA influenced the laboratory director to devote more funding or raise the visibility of technology transfer within the laboratory. Sometimes change was instigated simply by educating the laboratory director on the importance of technology transfer that leads to commercialization. At one laboratory, the ORTA laboratory director previously viewed interactions with the technology transfer office like going to the dentist—expensive and painful. The interviewee asserted that since she had been established as the new ORTA director, the relationship between the laboratory director and the ORTA had changed dramatically. The interviewee was successful in her efforts to explain the benefits and importance of technology transfer to the laboratory director, and now the ORTA engages in many more activities.

Some ORTA personnel stated they felt as if they have multiple, often competing, goals provided by laboratory and agency management. For example, some leadership may want the ORTA to be more aggressive in finding industry partners, while their agency general counsel may want the ORTAs to be more conservative. Or the ORTA may feel pressure to not license a technology and instead use it as an incentive to find a CRADA partner, while others would prefer it were licensed directly. This confusion in guidance can affect the ability of the ORTA to conduct technology transfer activities in an efficient and strategic manner.

The support from agency secretaries and laboratory directors for technology transfer and commercialization activities affects the ability of laboratories to perform these activities.

E. Organization and Coordination of Technology Transfer and Commercialization Activities

The organizational structure of technology transfer activities varies across the federal laboratories, both at the agency level and at the laboratory level. According to ORTA and agency-level technology transfer personnel, these variations affect the speed and magnitude of technology transfer. In addition, laboratory offices of research and technology applications are often not integrated with other technology commercialization programs within the federal government.

1. Centralization/Decentralization of Technology Transfer Authorities

The centralization of technology transfer offices vary among the different agencies. Signature authority for contracts can be held by the laboratory director (or commander for Department of Defense laboratories), by a central agency-level technology transfer officer, or by a combination of the two.

At some federal agencies, particularly those with multiple major laboratories, technology transfer authority is decentralized, but the agencies have a technology transfer coordinator who works with representatives at the laboratories to share best practices and to implement agency policy. For example, the DOD has had a technology transfer coordinator since 1995.[22] This office handles policy directives and coordinates activities, while negotiation and signature authority is delegated to the commander of each laboratory facility. In accordance with the Energy Policy Act of 2005, the DOE appointed a technology transfer coordinator in 2007. A joint appointee within the DOE held this position until April of 2010, when a single individual was hired. At the DOE, each laboratory has negotiation and signature authority, although agency-level approval is required in special situations, such as waiver of the U.S. manufacturing preference clause.[23]

In other cases, an agency-level technology transfer representative actually performs the legal work for the laboratories. Thus, all of the technology transfer activity is centralized. This is often the case for laboratories that have less intellectual property to process. For example, the Department of Homeland Security (DHS) has a technology transfer representative who handles all of the CRADAs and patents for DHS laboratories.

At some agencies, technology transfer is through a hybrid organization where the agency manages certain technology transfer activities and the laboratories handle other activities. The VA has a small office to handle the patents emerging from VA research hospitals, while the hospitals have the authority to enter into CRADAs without agency signature. The agency-level VA office provides support to the hospitals on certain CRADAs, typically for clinical trials. The NIH also has a central office for patents and licenses, while each individual NIH Institute and Center handles CRADAs and other collaborative research agreements. Since CRADAs include terms relating to licensing

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[22] Since DOD focuses on technology transition (incorporating technologies into DOD for use by or for the war fighter), the coordinator's title is the Director of the Office of Technology Transition.

[23] Stevenson-Wydler and Bayh-Dole require CRADA partners and patent licensees to use their own manufacturing facilities located in the United States, sign a manufacturing agreement with a U.S. manufacturer, or provide a plan for how the venture will benefit the U.S. economy. The DOE has a more stringent requirement that partners or licensees must manufacture "substantially" in the United States or provide an alternative net benefit to the economy. See DOE M 483.1-1 Art. XXII; 48 CFR 970.5227-3(f); 10 CFR Part 784.

inventions, an NIH-wide CRADA committee reviews and approves them with changes to model agreements requiring approval by the NIH Office of Technology Transfer (OTT).

At other agencies, there is no centralized agency coordinator, and no technology transfer activities occur at the agency level. For example, the Department of Commerce (DOC), whose laboratories are primarily located inside the National Institute of Standards and Technology (NIST) (with two large locations in Gaithersburg, Maryland, and Boulder, Colorado) and the NOAA laboratories, does not have a centralized technology transfer coordinator. NOAA has a centralized ORTA, but it primarily serves an administrative office rather than providing policy direction.

Based on our conversations with federal laboratory and agency technology transfer representatives, each approach has benefits and limitations. The completely decentralized arrangement allows for faster processes because laboratories do not need to involve an agency-level office, but it may also lead to inconsistent policies across the laboratories and more difficulty in disseminating strategies across the organization. Interviewees stated that it is critical to have a mechanism for laboratories to share best practices and ensure that any agency-wide policies are understood and uniformly implemented.

Laboratory ORTAs may not be aware of agency policies and best practices for accomplishing technology transfer at their agencies when structures are not in place for communication and coordination.

2. Location of Agency Technology Transfer Offices

The location of the technology transfer offices within the organizational structure of the agency also varies across the agencies studied. At some agencies, the technology transfer office is removed from the agency head. At one agency, the office is under one of several branches of the agency’s research and development (R&D) branch. The agency’s technology transfer coordinator asserted that this prevents the office from working effectively with other branches of R&D in the agency.

3. Location of Laboratory Offices of Research and Technology Applications

The location of each laboratory ORTA also varies. At some laboratories, the ORTA is buried in the organizational structure, limiting its ability to work with researchers across the laboratory and leading to inadequate visibility by the director. For example, some interviewees felt that their office was isolated by being placed within one of several research divisions. Others felt that their office was inappropriately isolated in the administrative division rather than the research division. The interviewees from these laboratories felt disconnected from researchers, hindering their ability to perform technology transfer efficiently and effectively.

Interviewees also stated that the location of the ORTA in a laboratory can influence the culture of the office and, in turn, their technology transfer activities. If the ORTA is located with other administrative offices, ORTA personnel asserted the office will have an administrative outlook. If the ORTA is located within strategic partnerships, however, it will have more of a technology development and commercialization focus. The variation in office placement can be seen by the following examples of office titles: Offices of Science Policy, Partnerships Offices, Administrative R&D Offices, Offices of Acquisitions and Grant Services, Offices of Chief Operating Officers, Division of Intramural Research, Office of Commercialization and Deployment, and Business Interface Office.

The location of the ORTAs within an agency and laboratory can affect the visibility of technology transfer and commercialization and the approach taken towards these activities, and may be an indicator of the importance placed on technology transfer and commercialization.

F. Offices of Research and Technology Applications (ORTAs)

According to interviewees, several factors that relate to the federal laboratories' ORTAs affect technology transfer that leads to commercialization. These include the training of ORTA personnel and the organizational structure of technology transfer offices, and ORTA processes, including technology transfer mechanisms and legal interpretations.

1. Expertise of ORTA Personnel

When the initial legislation for federal technology transfer was put in place over 30 years ago, the practice of technology transfer was not an established profession. According to the interviewees, laboratories frequently staffed their offices with bench scientists, some of whom were not focused full time on technology transfer. Since then, the literature has discussed the training needed to perform successful technology transfer activities, including knowledge of science, business, and law (Sheft 2008; Owen-Smith and Powell 2001). Interviewees echoed the literature, saying that ORTA personnel should maintain marketing and development experience, have knowledge of particular scientific fields, and be familiar with intellectual property processes and commercialization from an industry perspective.

ORTA staff interviewed had a diverse set of backgrounds, highlighting the heterogeneity of skills currently utilized in technology transfer offices. Professional experience ranged from bench scientist to technology developer for a business to patent attorney. Nevertheless, some interviewees stated that their offices needed additional expertise. The most common skill sets lacking were business development and marketing. As one ORTA representative stated, “We’re scientists not marketers,” and she felt that this was a detriment to finding effective industry partners.

Since technology transfer involves many different skills, education and training is often used to compensate for deficiencies in experience. Interviewees noted that introductory training opportunities for ORTA staff have significantly increased over the past decade. The Federal Laboratory Consortium for Technology Transfer provides agency-wide technology transfer instruction. Training is also offered at individual agencies and through undergraduate- and graduate-level classes and programs at universities. Some interviewed staff members had participated in these training programs, either as students or as instructors. The reviews on training courses, however, were mixed. One ORTA staff member pointed out that the two-week Office of Personnel Management course is insufficient to educate oneself on an entire field. Others felt that certain subjects, such as technology development, could only be learned by working for private industry.

At some laboratories, ORTA personnel may need additional expertise and training in certain aspects of technology transfer that leads to commercialization.

2. ORTA Responsibilities

Most of the ORTA staff interviewed stated that there are multiple facets to performing technology transfer that leads to commercialization. Two of the roles many ORTAs are asked to fulfill are the handling of administrative paperwork and the facilitation of technology development towards adoption by industry. Administrative paperwork includes the legal documents involved with applying for patents, signing Material Transfer Agreements (MTAs) and drafting CRADAs.[24] Technology development involves a host of other activities, such as finding industry partners or securing funding to develop technology to a point that it is mature enough to be licensed. At some of the ORTAs, interviewees reported that they were primarily or even solely focused on the administrative aspects due to resource constraints. For example, one agency interviewee stressed that she was the only person in the ORTA, which meant she found it difficult to do anything beyond the legally required activities. Another ORTA interviewee stated she would like to spend more time on the business development aspect of technology transfer, such as finding new industry partners, but the administrative aspect has to be done first. This interviewee also asserted that the administrative aspect has increased in recent years because science is becoming more collaborative and requires more materials and resources from across different institutions.

[24] MTAs govern the conveyance of tangible research materials from a federal laboratory to an outside entity.

In certain cases, these differing functions are broken into separate offices. A few of the interviewed federal laboratories have commercialization offices, in addition to an ORTA. For example, the DHS has an Office of Commercialization in addition to its Technology Transfer Program. The Office of Commercialization conducts outreach to the private sector, acts as clearinghouse of information, provides a point of contact for inquiries, supplies a face to the agency, and attempts to align operational requirements with market-based solutions.

There are differing responsibilities required of an ORTA. Some ORTAs are overly burdened with administrative aspects of technology transfer and do not have enough time to focus on technology commercialization aspects.

3. ORTA Processes

Interviewees also identified the internal processes of the ORTAs as a factor that affects technology transfer that leads to commercialization at the laboratories.

a. Processes of the Offices of Research and Technology Applications

ORTA interviewees acknowledged that while both facets of technology transfer are important, it is necessary to streamline processes so that the administrative aspect takes up less of the time and effort of the office. Some laboratory ORTAs have undertaken Six Sigma studies of their processes to eliminate unnecessary steps and to improve their administrative internal processes.[25] Others have begun using electronic agreements to reduce paperwork and the administrative burden. For example, one NIH laboratory uses a single email for Material Transfer Agreements, replacing the countersigned paper contracts that must be faxed three times. Another laboratory is developing an e-licensing system for commercial materials licenses that will significantly reduce the time to transfer important research materials to companies. NIH-OTT uses pay.gov, an online banking system, for the receipt of royalty payments, shortening processing time from several months down to a day in certain cases.

ORTAs have streamlined many of their administrative processes, but still often focus on administrative work rather than business development and outreach due to small staff size and increasing administrative burden of technology transfer requirements.

b. Invention and Negotiation Processes

The ORTA personnel interviewed take different approaches towards handling inventions and agreement negotiations. Some ORTAs do not have a noticeable volume of inventions and thus mostly have an *ad hoc* approach towards these topics. Those who

[25] Six Sigma is a strategy used to reduce process output variation.

manage a large intellectual property portfolio, however, employ several strategies to determine systematically which inventions should be patented or further developed to transfer out of the laboratory. Laboratories varied in their approach to deciding which inventions to patent.

Some ORTAs use a variety of strategies and resources to assess the feasibility marketability of inventions.

4. ORTA Authorities

We heard from interviews that some ORTAs have adapted the legal mechanisms authorized by statute, and that the interpretation of legal authority varies both across and within agencies. Both of these affect how technology transfer and commercialization occur at a laboratory.

a. Mechanisms Established Many Years Ago Have Been Modified

The Stevenson-Wydler Act and subsequent legislation gave laboratories authorities and mechanisms to engage in partnerships with industry in completely novel ways, and set in motion a series of partnerships that continue to this day. Some of the mechanisms established 30 years ago have been adapted over time to improve their function in the twenty-first century. Some examples of how agencies and laboratories have adapted existing mechanisms follow:

- The DOE, DOD, and NIH authorize their laboratories to use master CRADAs that allow for a single negotiation for several different projects with an industry partner.
- The NIH has developed a "Research Collaboration Agreement," which is essentially a Material Transfer Agreement plus aspects of a CRADA, but only for those research projects under which neither funds nor license or option rights to license inventions would be received or exchanged.
- In 1995, NIH initiated the development of the Universal Biological Material Transfer Agreement (UBMTA), which allows the efficient transfer of materials covered by the agreement between signatories using a relatively simple "Implementing Letter" for each transfer.
- In 1999, NIH developed the Simplified Letter Agreement (SLA) for the transfer of biological materials to minimize the administrative burden in negotiating Material Transfer Agreements.
- The DHS developed a "Secure CRADA" under which it tests technologies developed by industry. This CRADA has shortened agreement language.
- The USDA received authority under the 2008 U.S. Farm Bill to utilize Enhanced Use Leases (EULs) for technology transfer (U.S. Department of Agriculture 2011). An EUL is a public-private partnership whereby the private sector can

upgrade an under-utilized government facility in exchange for a long lease (30 to 50 years) at fair market value. The USDA is using the EUL mechanism to build long lasting research and licensing relationships with industry.

- When seeking materials from industry, the USDA uses Material Transfer (MT) CRADAs, which provide intellectual property protection through the typical CRADA format.

Furthermore, as noted previously in this report, agencies and laboratories do not have the same authorities to engage in technology transfer and commercialization activities. Appendix C lists some of the mechanisms and authorities that differ across the laboratories. The following examples illustrate the potential value from having these authorities:

- The Department of Transportation (DOT) Research and Innovative Technology Administration (RITA) is unable to use PIA legislation because it only covers federal laboratories and RITA is a grant making and research coordination agency. No single laboratory has enough technology for transfer to interest a partnership intermediary.
- Congress authorized the Armament Research, Development and Engineering Center at Picatinny (ARDEC) to provide engineering services, but it is still waiting on DOD implementation.
- Pacific Northwest National Laboratory (PNNL) can use the laboratory facilities to perform privately funded technology transfer under a special "use permit" (Provision 1831) from the DOE.

It was beyond the scope of this study to investigate fully why some agencies have authorities while others do not, or why a laboratory chooses to use or not use an authority given to them. Further study is necessary to understand this situation before determining whether other mechanisms are needed.

The federal laboratories do not all have the same legal authorities to engage in technology transfer. Some ORTAs have adapted the mechanisms available to them to accomplish technology transfer better.

b. ORTA's Interpretation of Legal Authorities

Legislative authorization for technology transfer mechanisms can be interpreted in different ways. Thus, when ORTA staff or agency leaders are risk-averse, they may interpret authorities more conservatively than if they were less risk-averse.

Differences in interpretation occur not only across the agencies but also in laboratories within the same agency. This can stem from confusion over agency policy. For example, interviewees from multiple laboratories within one agency had different opinions as to whether taking equity in a startup was possible. In addition, state laws can override federal agency requirements. For example, the DOE has given approval for Savannah River National Laboratory (SRNL) in South Carolina to exclude indemnity clauses from CRADAs with universities, because South Carolina law specifically prohibits this requirement.

In some of the larger ORTAs, the interpretation varied even within a single office. One interviewee stated that treatment of each partnership or license was dependent upon which ORTA agent received the file because each individual interpreted policies differently. In other cases, the variation was across an agency. During conversations, STPI noted that laboratories within the same agency differently interpreted policies related to taking equity in startups, the ability to grant exclusive licenses, and whether headquarters review of agreements was required or not.

ORTA personnel may not be operating under standard policies within an agency or even within an ORTA.

5. Use of Advisory Committees

Some ORTAs use advisory committees to help them perform their functions or improve upon their processes.

a. External Advisory Committees

Some of the federal laboratories have external advisory committees or other review processes devoted to technology transfer and commercialization activities. These groups provide guidance for improving commercialization processes and can serve as a source of commercialization expertise. The DOE National Renewable Energy Laboratory (NREL) Venture Capital Advisory Board meets quarterly. This board provides insight into how the ORTA is operating, and reviews the feasibility of NREL's technology maturation funding proposals. The DOE Idaho National Laboratory (INL) undertook a "peer-review" study to have its own office's processes studied by peers in the technology transfer arena. At the DOE's Technology Transfer Working Group meeting in November 2011, INL representatives stated that this review was useful for them to get an outside perspective on how they had been operating.

Most of the ORTAs whose representatives were interviewed do not have advisory committees or similar mechanisms for external oversight of their activities. Conversations with university technology transfer stakeholders revealed that advisory committees can help offices review processes, elaborate goals and practices, and identify any emerging issues or opportunities. Some of the laboratory interviewees stated that they would be interested in such a board to both facilitate their own practices and to gain outside expertise.

If GOGO ORTA staff members decide an advisory board would be beneficial, they must follow Federal Advisory Committee Act (P.L. 92-463) rules to set one up. Or if the laboratory already has an advisory board, a technology transfer and commercialization working subgroup could form to advise the ORTA staff. When non-federal employees are part of an advisory committee, they must follow Federal Advisory Committee Act guidelines (U.S. General Services Administration 2011).

Role of an Advisory Board

In a 2010 National Academies report on "Managing University Intellectual Property in the Public Interest," the National Academies discussed the role that an advisory board can serve for university ORTAs (NRC 2010). They suggest:

- the committee be composed of a mix of representatives from the university, industry, and business (such as business incubators, research parks, proof-of-concept centers, and entrepreneurship programs);
- the committee meet on a regular basis to provide advice on patenting, licensing, and identifying potential business opportunities; and
- a subcommittee of university-only representatives help to formulate technology transfer policy and make recommendations for change to the university leadership.

These suggestions might apply to federal laboratory technology transfer advisory boards as well.

b. Other Types of Advisory Committees

Agencies and laboratory ORTAs use a variety of committees to bring together the expertise needed to review invention disclosures, patent applications, CRADAs, and other mechanisms. They also have policy committees to provide input into technology transfer policies. Selected examples follow:

- The Public Health Services (PHS) Technology Transfer Policy Board is the principle advisory board for the NIH, the Centers for Disease Control and Prevention (CDC), and the Food and Drug Administration (FDA) on all matters pertaining to the Federal Technology Transfer Act. Its 13 members include 1 representative from the FDA, 2 from the CDC, and the remaining 10 from NIH. The PHS Policy Board makes recommendations on procedures involving patenting, licensing, fees, royalties, and CRADAs. The PHS Policy Board also serves as an advisor to FDA, CDC and NIH regarding these procedures, and provides technology transfer training and "scientific management." The PHS Technology Transfer Policy Board Policy Board has a CRADA Review

Subcommittee that oversees CRADA policies, and submits CRADAs to the PHS Policy Board for final approval (NIH 2002).[26]

- Invention Evaluation Committees and Patent Review Committees are used by some ORTAs (for example, DHS, AMRMC, and NIH) to review invention disclosures, patent applications, and other mechanisms used by scientists to transfer their technology. The committee, usually made up of laboratory staff, sometimes includes external members. These committees provide advice to the scientist about the readiness of the technology and next steps, for example, whether to develop the technology further or file for an invention disclosure.

Advisory committees can provide advice, knowledge and access to industry, and complement the skills of the ORTA staff.

G. Researchers

According to agency-level technology transfer office and ORTA personnel, researchers significantly affect technology transfer that leads to commercialization from the laboratories. Researchers need adequate knowledge, ability, and incentives to undertake the research, administrative aspects, and business development involved with technology transfer that leads to commercialization. Note, however, that these findings are not from the perspective of the researchers themselves, but from the perspective of agency-level technology transfer office and ORTA representatives we interviewed.

1. Importance of Researchers

Researchers play a critical role in technology transfer that leads to commercialization because without scientists and engineers working in the laboratories there would be no technologies to transfer. Beyond that, researchers must be willing and able to assist in the process of protecting their intellectual property. The protection of intellectual property involves filling out an invention disclosure, working with a patent attorney to prepare a patent application, and filing any necessary amendments.

ORTA staff must work across several different areas and are likely not experts in any one field. Interviewees said that researchers, on the other hand, are the experts in their areas and may have the best insight into which industries or specific companies would be candidates for research partners or licensees. There are many more researchers than ORTA staff, as well. If researchers are taught how, and are given the opportunity, to explain their research in a way that industry can see its commercial value, the number of "marketers" of the technology could substantially increase.

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[26] See http://sourcebook.od.nih.gov/comm-adv/ttpb.htm for more information about the PHS Technology Transfer Policy Board Policy Board and the CRADA Review Subcommittee.

Since technologies are rarely ready to be licensed at the point of invention, the inventor is often needed to continue to pursue research on the invention, or at least help guide what research would be required to make it marketable to industry. If the researcher is uninterested in pursuing further technology development, most laboratories stop the pursuit of transfer. One ORTA employee explained that if a technology is not found ready for patenting because it needs more work, then the ORTA works with the inventor to figure out the best path forward. If the scientist is not interested in continuing development, the ORTA staff member asserted that the possibility of protecting the technology as intellectual property is then dropped. Other laboratory ORTA personnel asserted that "researchers do technology transfer," and "it's very hard to do successful technology transfer if the innovator is not interested."

Researchers need the knowledge, time, and incentive to fulfill these roles. Stakeholders explained that if the accounting system of laboratory requires researchers charge each hour of their time to a project, researchers will be unable to work on technology transfer activities unless it fits within an existing project. Some stakeholders suggested that this issue could be resolved by having "technology transfer" or "business development" charge codes within a laboratory. Some of the strategies employed to engage researchers in technology transfer that leads to commercialization are discussed in the next section.

Researchers may be unaware of how to collaborate with industry or not understand the commercial potential of their research.

2. Education and Encouragement

Studies from the 1990s and 2000s found that researchers, themselves, can sometimes a hindrance to transferring technology. Responses from conversations with ORTA staff corroborated those findings from the literature. The ORTA staff felt most researchers were aware of the ORTA, but may be aware only of the administrative aspects of the ORTA, not the innovation process, how to interact with industry, or how to develop business. Several of those interviewed stressed the importance of "in-reach" to researchers to explain their importance in the technology transfer that leads to commercialization process.

The laboratories are employing several strategies to train and encourage researchers to engage in technology transfer that leads to commercialization activities. The first set of strategies involved training researchers to be aware of the aspects involved in starting a business. Two examples are:

- Several laboratories are training scientists in entrepreneurship topics through a third party (such as a partnership intermediary), through an affiliated business school or university, or by the ORTA staff.

- The Technology Ventures Corporation (TVC) at Sandia National Laboratories (SNL) has been a resource for SNL's researchers since Lockheed Martin took over the laboratory's contract in the early 1990s. TVC was designed specifically to facilitate the commercialization of technologies developed at SNL.

Some laboratories have strategies in place, such as entrepreneurial leave policies, to help researchers make the transition once they decide to start a company. The literature also supports these policies that allow laboratory employees to attempt to develop start-ups around technologies invented at the laboratory (Rogers, Takegami, and Yin 2001; U.S. Department of Commerce 2003). Several DOE GOCO laboratories, including Los Alamos National Laboratory (LANL) and Sandia National Laboratories (SNL), have Entrepreneurial Leave Policies. For example, SNL has established the Entrepreneurial Separation to Transfer Technology (ESTT) program that allows employees to leave to start a company. Reinstatement is guaranteed if the researcher returns within two years, and researchers can request an extension for a third year. The program was started in 1994, and nearly 140 SNL employees have participated in the program. ESTT alumni have started 44 companies and expanded 47 companies (Federal Technology Watch 2010).

Many ORTAs hold regular training sessions for researchers and are available for questions about the invention process. A few laboratories have entrepreneurship training and programs to allow scientists to start their own company.

3. Incentives for Researchers

Stakeholders suggested that researchers might feel that they do not have sufficient financial incentive to engage in transfer activities. For example, each agency or laboratory determines the exact percentage of royalties provided to the government inventor, though the minimum percentage required by statute is 15 percent (15 U.S.C. §3710c).

a. Royalty Distributions

Recognizing the role that researchers play in the technology transfer process, the Stevenson-Wydler Act states, "[t]echnology transfer, consistent with mission responsibilities, is a responsibility of each laboratory science and engineering professional" (15 U.S.C. §3710(a)(2)). In order to implement this policy, the legislation requires that the agency or laboratory head pay to the inventor or co-inventors the first $2,000 plus 15 percent thereafter of royalties or other payments received for a patent license (15 U.S.C. §3710c(a)(1)(A)(i)). Royalty payments for federal employees shall not exceed $150,000 per year to a single inventor.[27] The cap was originally $100,000 under

[27] GOCOs may place limits on the royalties distributed to inventors but there is no cap required by law.

Stevenson-Wydler, but was raised to $150,000 by the National Technology Transfer and Advancement Act of 1995 (15 U.S.C. §3710c(a)(3)).

The percentages of royalties given to researchers ranged from a minimum 15 percent up to 40 percent at Space and Naval Warfare Systems Command (SPAWAR). Most DOD laboratories follow a DOD instruction recommending that each inventor or group of inventors receive the first $2,000 plus 20 percent of the remainder of the royalties or other payments up to the legal cap of $150,000 (U.S. Department of Defense 1999). Some DOD laboratories (such as SPAWAR) go beyond the instruction, and others offer the minimum required by law. A sampling of the royalty distributions is shown in Table 4.

Table 4. Examples of Laboratories' Royalty Distribution Policies

Laboratory	Percentage of Royalties Distributed to Inventor
Space and Naval Warfare Systems Command (SPAWAR)	40%
Lawrence Livermore National Laboratory (LLNL)	35%
Lawrence Berkeley National Laboratory (LBNL)	35%
Agricultural Research Service (ARS)	25%
Air Force Research Laboratory (AFRL)	20%
Department of Health and Human Services (HHS) Laboratories	15–25%[a]
Pacific Northwest National Laboratory (PNNL)	15%

[a] HHS (NIH, FDA, CDC) gives the inventor 15% up to $50,000 or 25% up to $150,000.

The limits on the royalties distributed to inventors have not been changed by Congress since 1995.

b. Cash Awards and Commendations

The technology transfer legislation also mandates that each federal agency that spends more than $50 million per fiscal year on R&D shall develop a cash awards program to reward researchers for "inventions, innovations, computer software, or other outstanding scientific or technological contributions," or "exemplary activities that promote the domestic transfer of science and technology development" (15 U.S.C. §3710b). Laboratories comply with this by providing cash awards of several hundreds or even thousands of dollars for invention disclosures, patent applications, and patent issuance.[28] Laboratories also use recognition through commendations or awards to

[28] GOGO laboratories are limited to giving a researcher a maximum of two $500 cash awards up to $1,000 per year, although some GOGO laboratories make use of other award programs to award researchers.

incentivize researchers not only to innovate but also to seek intellectual property (IP) protection. Examples of the award systems used at various laboratories are as follows:

- Pacific Northwest National Laboratory (PNNL) hosts a formal annual awards ceremony, which the laboratory director attends. Researchers at PNNL can earn the "Top Inventor of the Year" award, as well as the title of "Distinguished Inventor" if they hold 15 or more patents.
- Savannah River National Laboratory (SRNL) hosts a reception event with the laboratory director ever year in which each patent recipient is recognized with an award. SRNL also gives researchers small monetary rewards ranging from $100 to $200 for submitting invention disclosures.
- Naval Surface Warfare Center Crane Division (NSWC-Crane) offers a $15,000 award to the scientists with the top three patents of the year. Cash awards for inventions and the patent approval process range from $200 to $500.
- NASA collaborates with the Space Foundation, which conducts the Space Technology Hall of Fame, a venue for recognizing space technology innovators.[29]
- The USDA ARS annually recognizes individuals or groups who have done outstanding work in transferring technology to the marketplace. There are two types of awards—an award for outstanding efforts in technology transfer over the previous 3 years and a sustained effort technology transfer award that recognizes research outcomes that have multiple stages of technology transfer that has development time of 5 to 15 years.[30]
- The Federal Laboratory Consortium for Technology Transfer also hosts several awards for researchers and technology transfer staff each year.

Interviewees from some agencies and laboratories would like to offer more incentives for researchers to do technology transfer, but do not have the resources.

c. Performance Evaluations

Aside from royalties and rewards, the Stevenson-Wydler Act stated that technology transfer activities should be included in researcher performance evaluations, laboratory job descriptions, and employee promotion policies (15 U.S.C. §3710(a)(3)). However, the majority of ORTA interviewees stated either they were not aware whether this requirement was implemented, or the requirement was not taken seriously by their laboratories. USDA was an exception; technology transfer weighs positively for

[29] Recognition is given to both intramural and extramural researchers. For more information on the Space Technology Hall of Fame, see http://www.spacetechhalloffame.org/.

[30] The 2011 ARS Technology Transfer Awards Program: Up to six awards are presented for the first award (two at $4,000 and six at $3,000) and one for the second award ($4,000).

researcher performance reviews and promotion decisions. In addition, Lawrence Livermore National Laboratory (LLNL) treats patents as equivalent to publications for performance evaluation purposes.

Researchers play a critical role in technology transfer and commercialization activities. The use of incentives and performance evaluations to encourage researchers to participate in technology transfer varies across laboratories.

H. Government-Industry Interactions

Several issues related to the interface between government and industry appear to affect technology transfer that leads to commercialization at the laboratories. Interviewees stated that the visibility and accessibility of the federal laboratories to those in industry, specific government rules and procedures, and timescale differences all affected the speed and extent of dissemination of technology transfer that leads to commercialization. Organizations known as partnership intermediaries are increasingly being used to facilitate interactions between government and industry.

1. Visibility and Accessibility to Laboratories

a. Industry Is Unfamiliar with Laboratories

According to conversations with partnership intermediaries, industry is largely unaware of the federal laboratories. Many in industry are unaware that there are business opportunities at the federal laboratories. For example, one partnership intermediary reported getting the sense from discussions at industry meetings about the ability for industry to collaborate with the federal laboratories that such alliances are relatively unknown to most companies. According to this intermediary, the laboratories "really don't promote themselves." This unfamiliarity can hinder the development of partnerships that drive technology transfer that leads to commercialization.

Several laboratories have developed technology showcases as a strategy to reach out to companies. These events take several different formats, but all serve to advertise laboratory capabilities or technologies developed in laboratories to industry representatives. Examples of technology showcases are as follows:

- Since 2002, the World's Best Technology Innovation Marketplace displays technologies, including those developed at the federal laboratories to venture investors and Fortune 500 licensing scouts.[31]

[31] For more information on World's Best Technology Innovation Marketplace, see http://www.wbtshowcase.com/wbt/web.nsf/pages/overview.html.

- Goddard Space Flight Center (GSFC) runs outreach meetings for Small Business Innovation Research (SBIR) Phase II companies in the mid-Atlantic and Northeast regions to advertise available laboratory technologies.
- The National Institute of Standards and Technology (NIST) has held several technology showcases, including one on NIST's nanotechnology capabilities.
- A number of laboratories within the National Institutes of Health and the Office of Technology Transfer (OTT) have participated in technology showcases sponsored by FLC Mid-Atlantic region and Maryland Technology Development Corporation (TEDCO), among others, to highlight available technologies.
- The Office of Naval Research (ONR) hosts the Navy Opportunity Forum, an annual event that allows companies to become aware of laboratory technologies that could be developed through SBIR (Phases I and II) proposals.

Several laboratories have developed strategies to make their technologies visible to industry.

b. List of Laboratories' Technologies for Transfer Are Not Easily Available

Even when companies understand that laboratory resources such as personnel and equipment are available for use, locating such technologies and capabilities can be difficult. Several laboratories and partnership intermediaries noted that many companies are unfamiliar with the resources that laboratories offer.

New companies, especially small businesses, may not have the resources required to perform intensive searches to know what technologies and capabilities the laboratories have.

Several ORTA staff mentioned the need for a unified intellectual property database that would alert industry to laboratory technologies. Such a database could eventually be expanded to include information on laboratory personnel and equipment in addition to available technologies. TechComm, a partnership intermediary, is working on integrating several of the agencies' and laboratories' internal databases onto one central server. The hope is that such an information source could become the precursor to a centralized IP database. Several laboratories have made information readily accessible on their technologies available for licensing using automated electronic feeds, such as RSS, which have been featured on OpenGov, the Open Government Initiative website (http://www.whitehouse.gov/open). Interviewees stated that if all agencies and laboratories could make such information available in real time through RSS, it would facilitate further private-sector innovation around the development of web- or smartphone-based resources for all federal laboratory inventions enhanced with full-text searching and visualization tools.

Several laboratories have already developed databases in an attempt to promote their available IP to interested industry partners. In some cases, information is available for an entire agency's laboratories; in other cases, information is available for only one laboratory or a subsection of an agency's laboratories. Examples of technology portals are listed here:

- The Federal Laboratory Consortium for Technology Transfer provides a congressionally mandated online locator service through which interested parties can request to be put in contact with the appropriate laboratory or center.
- The NASA TechFinder database is a publicly searchable database that allows industry to locate relevant licenses, technologies, and collaboration opportunities and submit requests to collaborate with NASA.
- The DOE Office of Energy Efficiency and Renewable Energy developed a searchable website listing the energy-related technologies of nine DOE laboratories. The Energy Innovation Portal allows users to search several thousand patents and patent applications, as well as several hundred technology marketing summaries.
- The NIH offers a website with lists of many available NIH and Food and Drug Administration (FDA) technologies, including the ability to register for an RSS feed and an iPhone app of available technologies and technology updates. FDA is currently creating a technology portal to make its technologies more readily accessible to interested partners and potential licensees.

Creation of intellectual property databases and websites is a necessary first step at reaching out to companies and other interested partners. It is important to note, however, that their mere creation alone will not overcome the problem of industry's unfamiliarity with the federal laboratories as a whole.

c. Office of Research and Technology Applications (ORTA) Contacts Are Difficult to Locate

Once industry representatives are interested in a laboratory's resources, it is often difficult for them to locate a laboratory representative with whom to discuss possible partnerships, according to interviewees. According to an anecdote provided by a partnership intermediary, it can take up to five calls to five different people at five different laboratories (for a total of 125 calls) in order to locate the correct person to talk to at a technology transfer office. In fact, partnership intermediaries reported that one of their main functions is to connect businesses that are unfamiliar with the laboratories to the correct laboratory representative. The FLC provides a list of all laboratory ORTAs and links to websites where possible, but this database was not mentioned in interviews with partnership intermediaries.

We conducted our own analysis of the location of technology transfer offices relative to their agency's homepage. Larger agencies did not provide technology transfer lists on their homepage. Instead, they were available only through a separate entry point housed by a specific subagency or parent department. Ease of accessing the ORTA at the agency level did not correlate with ease of access at the laboratory level. In some cases, accessing the laboratory ORTA was easier through an agency website entry point and in other cases easier from the laboratory website entry point.

According to interviewees, difficulties associated with lack of visibility and access to the federal laboratories is exacerbated for small businesses. Partnership intermediaries mentioned that small companies often lack the time, money, and staff necessary to navigate the landscape of the federal laboratories. According to a representative of an interviewed partnership intermediary, small companies often "don't have the internal capacity to work with the labs." For this reason, both formal and informal partnership intermediaries play an important role in connecting laboratories with businesses that do not have the resources to navigate the federal laboratory system.

In order to overcome the lack of visibility, many ORTA staff stated they spend time networking at conferences and workshops. This can be a challenge, however, when staff is limited.

Federal laboratories are not visible and accessible to industry. It can be difficult to find the laboratories' technology transfer websites.

2. Government Rules and Procedures

An oft cited barrier in the technology transfer literature is government-specific rules and procedures (Jaffe 2000; Markusen and Oden 1996). Government laboratories are considered to be more difficult to work with than GOCO laboratories and universities because they must comply with advanced payment requirements, product liability insurance requirements, indemnity clauses, U.S. manufacturing preference rules, Federal Acquisition Regulations, conflict-of-interest rules, fairness-of-opportunity requirements, and grant rights to compel and royalty-free use licenses to the government (see box for descriptions). For example, one laboratory interviewee stated that some organizations simply could not live with granting the government a royalty-free use license under a CRADA, so about 5 percent walk away from the table.

DOE Policy Barriers to Industry-Laboratory Interactions

The Department of Energy (DOE), as part of an ongoing review of technology partnering agreements, issued a Request for Information (RFI) in November 2009 to understand the issues faced when partnering with DOE laboratories. DOE received thirty-six responses by January 2009.

The issues raised by respondents were primarily around four main topics.

Indemnification: Federal laboratories are free from paying compensation or damages in the event that a technology developed under a CRADA infringes upon other intellectual property or any other claims arise.

Advance funding requirement: Currently all DOE laboratories require either 90-day or 120-day advance funding prior to the start of work for a CRADA.

DOE's U.S. competitiveness requirement: Legislation requires a preference for U.S. manufacturing for any intellectual property stemming from a CRADA, although the DOE has specific guidance that makes this requirement more stringent than at other agencies.

Sponsor retaining title to intellectual property in Work-for-Others (WFO) agreements: Regulations do not take into account rights to intellectual property that result from WFOs, which leaves space for contention over the issue.

In response to the DOE Notice of Inquiry, the DOE Technology Transfer Coordinator and the DOE Technology Transfer Working Group (TTWG) Executive Committee prepared four white papers to address each of these points and are now working to address the identified issues.

The problem does not necessarily lie within the statutory language, but in how the agency or laboratory interprets it. Some agencies have developed policies beyond what is required by statute that further hamper partnerships or transfer of technology. A laboratory employee pointed out that the problem is "not legislation, it's [agency] policy." For example, the DOE has a more stringent U.S. manufacturing preference requirement than is in the technology transfer legislation.

Some agencies have worked hard to develop policies that are workable for industry partners. For example, the USDA worked with counsel and deleted liability insurance and indemnification provisions from its partnership agreements. Another agency uses segmented CRADAs to lessen the impact of the advanced payment requirement. The agency draws up the agreement for a portion of the partnership so the company is only required to pay for that part and then amendment(s) cover the remainder of the work.

While many interviewees identified specific government procedures or regulations that were hampering technology transfer and commercialization, an equal number asserted that these barriers could be worked around. "There are regulations for everything, [we] just must figure out how to get through them." Small- and medium-sized businesses are less likely to have experience working with the government, so this issue affects them disproportionately. Interviewees said such experience is of primary importance, or lacking that, a willingness to be educated is necessary. Even if the company is new to working with the federal government, the deal could still flow smoothly as long as the laboratory technology transfer officer or attorney took the time to explain which provisions were non-negotiable and why. However, sometimes no amount of instruction will make a difference. One laboratory interviewee asserted that, the industry defense attorneys "are acquisition people, so they don't take time to understand what they're asked to do."

Selected Federal Technology Transfer Contract Terms

Required by statute:

Royalty-free License to Practice (or "government-purpose rights"): The government is required to preserve a license to practice or have practiced on its behalf patent licenses or licenses stemming from CRADAs (15 U.S.C. §3710a(b)(2)).

Rights to compel a license: If the patent licensee has not taken effective steps toward application, and the invention is necessary to alleviate health or safety needs or meet requirements for public use, the government may use its rights to compel the contractor to grant a license to the invention to a responsible party (15 U.S.C. §3710a(b)(1)(B)-(C)).

Recommended by statute:

U.S. Manufacturing Preference: The laboratory director in deciding what CRADAs to enter into shall give preference to business units located in the United States which agree that products embodying inventions made under the CRADA or produced through the use of such inventions will be manufactured substantially in the United States and, in the case of any industrial organization or other person subject to the control of a foreign company or government, as appropriate, take into consideration whether or not such foreign government permits United States agencies, organizations, or other persons to enter into CRADAs and licensing agreements (15 U.S.C. §3710a(c)(4)(B)).

***Preference for Small Businesses*:** The laboratory director in deciding what CRADAs to enter into shall give special consideration to small business firms, and consortia involving small business firms (15 U.S.C. §3710a(c)(4)(A)).

***Common Terms*:**

Product liabilit insurance: The participant (or the contractor for GOCO laboratories) agrees to purchase and maintain adequate product liability insurance to protect the government (and the contractor for GOCO laboratories) against product liability claims.

Indemnity: Participant agrees to indemnify the government (and defend the contractor if a GOCO) against any claim or proceeding and pay all damages, costs, and expenses, including attorney's fees, arising from personal injury or property damage occurring as a result of the making, using, or selling of a product, process, or service by or on behalf of the Participant, its assignees, or licensees, which was derived from the work performed under this CRADA.

Source: Interviews and statutes cited.

Several agency policies related to legislative provisions are troublesome for industry when collaborating with the laboratories.

3. Copyright Prohibition

When the Stevenson-Wydler Act was implemented at the beginning of the 1980s, software was still in its infancy and not recognized as an important element of government-funded research. However, this is no longer the case.

Exclusivity is important for commercialization, but it is difficult to provide for software. As government entities, GOGO laboratories are prohibited from asserting copyright, which would provide instantaneous protection upon invention. Some software is patented, but this is a slow process unsuited to the fast-paced software industry. Copyright provides instantaneous protection upon invention. One agency asserted that the lack of copyright protection acts as a disincentive for researchers to engage in software development because their work is not protectable.

CRADA partners can copyright their inventions, but there are still questions surrounding software that has been co-developed. Software developed at DOE GOCO laboratories does have the potential for copyright protection and DOE has recently updated its procedures pertaining to copyrights for open source software. Even if software is open source, it is important to secure copyright protection to provide a level of control and prevent distortion of the underlying code. Some GOGO laboratories have found creative ways to assert copyright protection. For example, one laboratory ORTA employee explained that the laboratory obtains copyrights for software by asking the industry partner to assert the rights to the intellectual property, and then assign those rights to the laboratory.

While GOCO laboratories can copyright software, GOGO laboratories do not have the ability to copyright.

4. Different Government and Industry Timescales

Literature from the 1990s reported that industry partners were critical of the length of time the government required to complete technology transfer agreements (Rogers et al. 1998). Conversations with personnel from agency-level technology transfer offices and Offices of Research and Technology Applications indicated that federal government and industry timescales still often differ. Several partnership intermediaries reported that one of the most frustrating aspects of working with the laboratories is the length of time required to reach an agreement. Some federal agencies and laboratories also indicated that delayed agreement can burden government-industry interactions. As each agreement must pass through several stages from generating the concept, negotiating and drafting, and signing to execution, delays at any stage can make such formal partnerships difficult to finalize.

Several laboratory and agency interviewees reported concern regarding the length of time that it takes to reach agreements, some indicating that excessive length can result in losing a contract. A few laboratory ORTA staff members reported that they had lost contracts—not because the agency answered no, but because they never said yes. Personnel from another laboratory stated that the governance model within their agency slows down their processes; nine different individuals are required to approve each Work-for-Others (WFO) agreement and CRADA, which leads to an approval time of approximately 6 months. A third laboratory interviewee stated that companies struggle with the 4- to 8-month period that it takes for her office to sign a CRADA, and the laboratory sometimes ends up losing out the partnership agreement. An agency interviewee stated that one of their biggest barriers is slowness in signing an agreement.

GOGO laboratories must comply with more procedures than GOCO laboratories, and this may require additional time. Some of these rules are mandated by statute, and others have been developed as best practices. For example, laboratories must publish their intent to grant an exclusive license for 15 days in the Federal Register (Patents, Title 35 U.S. Code, §209(e) (2010)). Beyond the actual period of circulation, person-hours must be spent drafting, editing, and approving the write-up, not to mention fulfilling the steps necessary to secure publication. In addition, GOGO laboratories must be especially diligent to avoid conflicts of interest and ensure fairness of opportunity. "We work hard to prevent unfair competitive advantage and organizational conflict of interest," remarked one laboratory ORTA representative. Such ethical oversight requires the extra steps of identifying and communicating with stakeholders who may have an interest in the outcome of the partnership agreement.

Although concerns over the time that it takes to reach an agreement exist, it is important to note that many ORTA representatives contend that frustration is often not the fault of the laboratory. Many laboratory interviewees stated that bottlenecks most often occurred on the industry side of the negotiation process, and both partnership intermediaries and federal laboratories mentioned the importance of managing expectations related to agreements.

While the problems may occur on both sides of the negotiation, several laboratories and agencies are taking steps to ensure that their procedures are streamlined. One approach is to begin by recording the time required for each step in the process. For example, one agency studied where bottlenecks occurred. Another agency commissioned a best practices study to examine the amount of time it takes to get CRADAs signed at several of their laboratories, and is now studying the causes of the variation seen across the laboratories. While there has been interest in streamlining the process further by having model agreements across all agencies, one agency interviewee pointed out that this is often not possible due to the different types of technologies invented across laboratories and agencies.

According to industry, the timeline for reaching agreements is a barrier to working with laboratories.

5. The Role of Partnership Intermediaries in Assisting Government-Industry Interactions

Several of the federal laboratories that participated in discussions rely on the use of formal or informal partnership intermediaries to facilitate interactions between laboratories and industry. Partnership intermediaries exist to help laboratories navigate the technology development and commercialization processes. These organizations often undertake functions that the laboratory either cannot do or is not well suited to doing.[32] According to the TechLink representative, the job of a partnership intermediary is to make the "red tape invisible to [the] company." See Table 5 for a complete list of partnership intermediaries whose representatives we interviewed.

Table 5. Partnership Intermediaries Interviewed and Their Associated Agencies

Partnership Intermediaries	Associated Agencies
FirstLink	DOD
Kansas Bioscience Authority	USDA
MilTech	DOD, DOE, HHS, USDA
National Association of Seed and Venture Funds	DOD, USDA
TechComm	DHS, DOD, HHS, USDA
TechLink	DOD, NASA
Maryland Technology Development Corporation	DOC, DOD, NASA, HHS, NSA, USDA

TechLink signed the first formal Partnership Intermediary Agreement (PIA) and it first collaborated with NASA in 1998. The DOD has been using PIAs since 1999. Together, the five DOD PIAs form the DOD Office of Technology Transfer Partnership Intermediary Network (OTTPIN). The USDA recently started the Agricultural Technology Innovation Partnership (ATIP) program consisting of eight regional partners and one national partner. Several other agencies have formally or informally used partnership intermediaries to increase the commercialization of technologies developed in their federal laboratories.

Some PIAs provide specific activities or are targeted for specific sectors or geographic areas. For example, FirstLink was created to spin out DOD technology to the first responder community. MilTech identifies an industry partner early on and develops

[32] A partnership intermediary is "an agency of a State or local government, or a nonprofit entity owned in whole or in part by, chartered by, funded in whole or in part by, or operated in whole or in part by or on behalf of a State or local government, that assists, counsels, advises, evaluates, or otherwise cooperates with small business firms, institutions of higher education as defined in section 1141(a)(1) of title 20, or educational institutions within the meaning of section 2194 of title 10, that need or can make demonstrably productive use of technology-related assistance from a federal laboratory, including state programs receiving funds under cooperative agreements entered into under section 5121(b) of the Omnibus Trade and Competitiveness Act of 1988" (15 U.S.C. §2781 note).

prototypes of the technology to facilitate the transfer. The Maryland Technology Development Corporation (TEDCO), was established by the State of Maryland to facilitate the transfer and commercialization of technology from Maryland's research universities and federal laboratories into the marketplace.

What Is a Partnership Intermediary Agreement (PIA)?

- PIAs allow federal research agencies to enter into an agreement with a non-profit organization (partnership intermediary) to assist the federal agency with its technology transfer efforts.
- The partnership intermediary's services complement those of the federal laboratory and increase the likelihood of success in conducting cooperative or joint activities between the federal agency and a partnering organization (businesses, universities, or other federal agencies).
- These agreements can help strengthen state and national economic development and help U.S. businesses compete globally in the marketplace.

The partnering organization offers many benefits to federal laboratory researchers, including:

- identifying potential research partners and licensees,
- increasing access to a variety of businesses,
- providing industry perspective on federal laboratory technologies,
- increasing the likelihood of impact from research outcomes,
- identifying potential funding sources for research scientists, and
- expanding customer and stakeholder interactions with the private sector and other federal agencies, e.g., food safety and environmental agencies.

Source: USDA ARS *Partnership Intermediary Agreements (PIA) and Technology Transfer* brochure, http://www.ars.usda.gov/SP2UserFiles/Place/36200000/OTT-S2.pdf.

In recent years, laboratories have started working with partnership intermediaries to help partner with industry. Some have started to form networks for working with specific agencies.

I. Resources

The literature highlighted that the fact that technology transfer is an underfunded legislative mandate can adversely affect technology transfer activities (Riggins and London 2009). Since funding for technology transfer must be carved out of existing budgets, active opposition to technology transfer can arise because it is seen as funneling away critical funds that should be used for mission-based research (Spivey, Munson, and Flannery 1994). Interviewees confirmed that underfunding of technology transfer that leads to commercialization is still a significant problem today. When interviewees were asked what barriers prevented them from doing more technology transfer that leads to commercialization, the most common answer was a lack of dedicated and sustained resources. Three-fourths of the laboratories and agencies stated that funding shortages are a barrier. The study also found great variation in the magnitude of funds devoted to technology across the laboratories and agencies based on the size of the ORTA staff relative to the laboratory size.

1. Legislation and Resources for Technology Transfer that Leads to Commercialization

The Stevenson-Wydler Act did not designate how much funding should be devoted to technology transfer and commercialization activities beyond stating "each Federal agency which operates or directs one or more federal laboratories shall make available ***sufficient funding***…to support the technology transfer function at the agency and at its laboratories, including support of the Offices of Research and Technology Applications" (15 U.S.C. §3710(b)(2); emphasis added). Furthermore, major federal laboratories[33] are required to provide "one or more full-time equivalent positions as staff for its Office of Research and Technology Applications" (15 U.S.C. §3710(b)(1)) as well as provide support for the FLC.

The Stevenson-Wydler Act and subsequent legislation did not designate how much funding should be devoted to technology transfer and commercialization activities.

2. Variation in Resources Devoted to Technology Transfer that Leads to Commercialization

Although STPI did not receive ORTA budget figures from the laboratories, an analysis of the ratio of the number of ORTA staff to the number of researchers shows wide variation in the staff resources devoted to technology transfer and commercialization across the agencies and laboratories. Table 6 shows that the number of ORTA staff varied from 1 person up to more than 50 people, and the ratio of ORTA staff compared to the number of R&D staff varied from less than 50 researchers per ORTA staff to over 2,500 researchers per ORTA staff. The table shows a sampling of these ratios. Because of the differences in scope of responsibility, it is not a precise comparison. For example, the NCI office does not manage patent prosecution and licensing whereas other offices listed do. However, NCI has responsibilities for 9 additional NIH Institutes.

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[33] Originally under Stevenson-Wydler, all laboratories with budgets greater than $20 million were required to staff an ORTA. The criterion was changed to be all laboratories with 200 or more full-time equivalent scientific, engineering, and related technical positions by the Federal Technology Transfer Act of 1986.

Table 6. Rough Estimates of the Ratio of ORTA Staff to R&D Staff for Selected Laboratories

Laboratory	ORTA Staff	R&D Staff	Researcher/ ORTA Ratio
National Cancer Institute (NCI)	33	1,912	~58
Oak Ridge National Laboratory (ORNL)	38	4,416	~116
Lawrence Berkeley National Laboratory (LBNL)	17	3,204	~188
National Institute of Standards and Technology (NIST)	8	2,881	~360
Goddard Space Flight Center (GSFC)	7	3,250	~464
Army Armament Research, Development and Engineering Center (ARDEC)	5	3,600	~720

Note: Some laboratories split out different technology transfer functions. For example, the NCI staff numbers represented above do not include the NIH OTT staff who handle the patenting and licensing of NCI technologies.

Interviewees stated they were in need of resources in the form of either staff or funds, or both. The desired use of these resources also varied, depending on the particular needs of the ORTA. One agency ORTA representative gave the example of a request for funds to purchase a database system to house the agency's CRADAs and intellectual property portfolio. The interviewee stated that it ultimately took 18 months for the system to be purchased. Other ORTA stakeholders asserted that more staff would enable the office to focus on more of the business development and marketing aspects of technology transfer that leads to commercialization.

ORTAs require a stable budget for planning and implementing technology transfer and commercialization activities.

3. Technology Transfer Not a Self-Sustaining Activity

ORTA staff interviewed said that at many laboratories, the likelihood of receiving significant revenue royalties is small. Therefore, many offices involved with technology transfer are at risk if they are expected to be self-sustaining using these revenues. For example, at one agency, severe downsizing of the ORTA (from 10 employees to just 1) occurred after the expiration of a single profitable license.

These large swings in staff size and resources can be prevented if technology transfer revenues are used to supplement an office's budget, but not as the primary source of funding for core activities. The DOE's Lawrence Livermore National Laboratory (LLNL) ORTA is funded by laboratory overhead and it receives 15 percent of all laboratory-based royalty revenue for use in a technology maturation fund. LLNL's ORTA personnel reported that because of their substantial revenue, they have been able to sustain this program. Of course, the technology maturation fund would be in danger if royalties significantly drop, but the main ORTA functions would not be affected.

When expected to be self-sustaining, the incentives of an ORTA are misaligned with increasing the broadest distribution of technologies as quickly as possible. Stakeholders asserted that ORTAs might hold onto intellectual property in the hopes of getting the "best" deal possible with respect to royalties, while the intellectual property is losing value because of the temporal nature of the protection. Furthermore, if the laboratory itself is constrained on resources, the ORTA may be pressured to hold onto a technology in the hopes of getting a large CRADA partner as opposed to getting the technology out to a potential developer as soon as possible.

Treating technology transfer that leads to commercialization as a self-sustaining activity can result in misaligned incentives.

4. Resources for Technology Maturation

Often the technologies that are developed at the laboratories are at an early stage and require further work to determine their feasibility for commercialization. Several laboratory staff members specifically stated they are in need of resources to fund development of technologies that require additional work before transferring to industry. Interviewees at laboratories or agencies that have access to technology maturation funds supported their worth.

The Commercialization and Deployment Team of the office of Energy Efficiency and Renewable Energy (EERE) administers a $14 million Technology Commercialization Fund (TCF). TCF bridges the gap between program funds and the market for the technology. EERE programs may then pick the project back up for further development once TCF funds have been used to show it could be commercialized. Currently, 52 projects across eight national laboratories cover a wide range of subjects.

Partnership intermediaries are also a source for technology maturation funds. The DOD established a PIA with MilTech, a partnership intermediary that specializes in producing physical prototypes. One laboratory representative stated it is instrumental in convincing licensees to go forward with commercialization. Maryland TEDCO recently established a technology maturation program known as the Joint Technology Transfer Initiative (JTTI).[34] The JTTI awards grants of up to $75,000 for technologies that either spin-in or spin-out to the DHS or the AMRMC. Awards are given to small companies, who are expected to supply a 50 percent match to the award, either in direct or in-kind expenses. Virginia's Center for Innovative Technology (CIT) manages CIT GAP Funds, which "makes seed-stage equity investments in Virginia-based technology and life science companies."[35]

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[34] For more information on JTTI, see http://www.marylandtedco.org/publications/JTTI.cfm.

[35] For more information on CIT GAP Funds, see http://www.citgapfunds.org/.

For technologies further down the development pipeline, Battelle has established Battelle Ventures, a $225 million fund for seeding early-stage technology companies. Battelle Ventures funds technologies beyond those emerging from Battelle-managed laboratories, but they state that they have close relationships with the ORTAs in the Battelle laboratories. Areas of interest for the fund are health and life sciences, energy and environment, and security.

Many of the technologies invented at the laboratory are at an early stage and require further development before they can be transferred to industry.

5. Leveraging Economic Development Programs

A number of federal, state, and local programs support economic development, sometimes specifically through technology commercialization or technical assistance. For the most part, ORTAs are not linked to other programs that support economic development and commercialization. Technology transfer requires skills and expertise that differ from the traditional skills found in nontechnology-based federal, state, and local economic development programs. While both aim to promote the economic and social well-being of a specific region or the entire nation, the laboratory ORTAs and federal, state, and local economic development programs typically operate completely independently.

The federal government has established a variety of programs to support technology commercialization, most of which are focused on supporting commercialization of extramural research. Many of these are located within the Department of Commerce, although several other agencies have developed programs specifically to advance the development of the technology or directly address commercialization to meet their own missions, or do both. Some examples of programs that address the commercialization of technologies include:

- The Economic Development Administration’s University Center Program provides funding to universities to improve the economies and economic development capacity of the center’s service areas.
- The National Science Foundation’s Accelerating Innovation Research program funds a Technology Translation Plan Competition and a Research Alliance Competition. Both of these are designed to accelerate the transition of fundamental knowledge into novel products and processes.
- NIST’s Technology Innovation Program aims to support, promote, and accelerate innovation in the United States through funding small- and medium-sized businesses, or public-private partnerships, to conduct high-risk, high-reward research in areas of critical national need.

- NIST’s Hollings Manufacturing Extension Partnership (MEP) works with small and mid-sized U.S. manufacturers to accelerate innovation (see box).
- The Economic Development Administration, in conjunction with the National Science Foundation and the National Institutes of Health, launched the i6 Challenge program in 2010. The i6 Challenge funds ideas for technology commercialization and entrepreneurship for up to $1,000,000 per award. One of the sets of winners included Technology Ventures Corporation, an organization that was created explicitly to help commercialize technologies emerging from Sandia National Laboratories.

In many situations, federal laboratories are not permitted to receive funds through federal, state and local programs. Some interviewees stated this makes it difficult for the laboratories to enter into partnerships with others who may be funded by the program. Although a full analysis of the requirements for these programs was not performed, a scan of the request for applications showed in many cases that federal laboratories were prohibited from receiving funds through the program.

There are a variety of federal programs designed to support economic development through technology commercialization, yet most are aimed at university-based researchers and industry, and do not permit federal laboratories to participate.

Manufacturing Extension Program

The National Institute of Standards and Technology’s (NIST)Hollings Manufacturing Extension Partnership (MEP) works with small and mid-sized U.S. manufacturers to help them create and retain jobs, increase profits, and save time and money. MEP also works with partners at the state and federal levels on programs that put manufacturers in position to develop new customers, expand into new markets and create new products. MEP includes over 1,400 technical experts located in every state, serving as business advisors, focused on solving manufacturers’ challenges and identifying opportunities for growth.

By providing a direct connection between the manufacturing marketplace and the research laboratory (whether federal, university, or private), MEP helps ensure a necessary two-way linkage exists:

- From the research side, MEP helps get laboratory technologies into the hands of manufacturers that will produce and commercialize them
- From the manufacturing side, MEP helps get the needs and perspectives of the marketplace into the hands of the researchers to help guide the direction of research focus to meet know market needs

Once a technology-to-manufacturer connection is made (in either direction), MEP also plays a role in working with companies to commercialize those technologies. (See http://www.nist.gov/mep/partners/.)

One example of the federal laboratories leveraging these programs is the Small Business Innovation Research Technology Transfer program (SBIR-TT), piloted at

National Institute of Standards and Technology (NIST) and now being adopted by others, such as the National Cancer Institute (NCI). This program uses Small Business Innovation Research (SBIR) funds to further develop technologies that were initially created at the laboratories (see box for more information).

Small Business Innovation Research—Technology Transfer

The Small Business Innovation Research—Technology Transfer (SBIR-TT) program was developed at NIST in 2007. One of the goals of the original SBIR program was to "increase private sector commercialization of innovations derived from Federal R&D." This has traditionally been interpreted as promoting commercialization of innovations arising from R&D performed extramurally, but the SBIR-TT program extends the interpretation to include innovations developed at the federal laboratories themselves.

At NIST, researchers identify commercially promising NIST technologies—some patented and some not, as well as the research challenges that are restraining their commercialization. These technologies are placed in the SBIR-TT solicitation (alongside traditional topics, focusing on NIST research needs) and, if selected, awardees are given a non-exclusive research license to relevant patents. The SBIR proposal research plan acts as the license application and awardees are given the option of a future non-exclusive commercialization license. Furthermore, the grantees have access to NIST facilities, personnel, and knowledge.

Since its inception, federal agencies have viewed the SBIR-TT program as a success. The NIH announced its own SBIR-TT program with inclusion of two NCI-patented technologies in the recent NIH SBIR solicitation. The Navy, DOT, and other NIH institutes are in the process of launching pilot programs using this model and others (NASA, USDA, EPA, and DOE) are in the exploratory stages.

J. Summary

Several factors appeared to affect technology transfer that leads to commercialization at the laboratories. These factors are not independent of one another, and how strongly they affect technology transfer that leads to commercialization depends on the characteristics of the laboratory. For example, many laboratories doing research that is likely to be useful to industry do not have the funding to allow researchers to engage in collaborative research activities with industry. Nor do they have sufficient resources to facilitate technology transfer from the laboratories. Laboratories could consider implementing some of the strategies presented in this chapter and in Chapter 7 to increase their technology transfer that leads to commercialization activities.

6. Measuring Technology Transfer and Commercialization Success

One of the charges of this study was to discuss potential metrics that could be used to measure the success of technology transfer that leads to commercialization at the federal laboratories. The point made in the last several chapters, namely that the federal laboratories represent a diverse spectrum of entities with varied missions and authorities, is important for this chapter, as metrics developed must tie directly to the goals of technology transfer that leads to commercialization in the context of the mission and scope of each laboratory.

This chapter discusses some of the concepts around defining and measuring success, beginning with a general overview and then focusing on how metrics are currently used to assess technology transfer government-wide, by specific agencies, and by individual laboratories. It also explores whether these metrics are sufficient for their possible intended purposes. Next, it presents additional metrics for consideration and discusses the feasibility of collecting those metrics. The chapter concludes with implications of the findings from this chapter for the rest of the study.

A. Defining and Measuring Success

1. Overview of Metrics

According to Merriam-Webster Online, a metric is a standard of measurement (Merriam-Webster Online 2011). This definition is independent of context, yet the term is commonly used within the framework of evaluating performance.

Using metrics as a performance management tool raises several challenges. When the actual outputs and outcomes of a program are intangible or multidimensional, as is often the case, metrics are merely proxies for the outputs and outcomes. Given this, it may be useful to think of metrics in this context as "indicators"—defined as observable and measureable characteristics of abstract concepts, each of which only captures a part of complex reality (Hill and Roessner 1998). That is, metrics should not be seen as the goals themselves, but instead should be viewed as a way to understand a phenomenon. For certain phenomena, a single metric can be used. More frequently, however, programs, processes, and other entities of interest are of sufficient complexity to require multiple measures. Furthermore, because metrics are often seen as measures of success, care must be taken in how they are used, lest behavior be driven to maximize a given metric in such a way that compromises achievement of the broader fundamental program objective.[36] Metrics can be used in a variety of ways (see Table 7).

Table 7. Different Purposes for Using Metrics, with Hypothetical Examples

Purpose	Example
For internal management	Identify specific activities that are contributing to the laboratory's goals and identify those that are not
To understand specific phenomena	Assess the factors that affect laboratory-industry interactions
To answer stakeholder questions	Identify how many small businesses worked with the laboratories over the past year
To meet official requirements	Report on the metrics required in the annual report on technology transfer activities
To promote interest and support	Highlight the effect that laboratories have on local economic development

Source: Adapted from Ruegg and Feller (2003), Table 1-1.

Several different types of metrics can be used to describe and evaluate a program:

- *Input metrics* typically describe the resources available to a program. In the context of technology transfer, input metrics could include the funds devoted to R&D, the mix of funds devoted to basic vs. applied vs. development work, the funds devoted specifically to technology transfer, and the number of staff devoted to technology transfer, among others.
- *Activity metrics* describe the actions taken. In this context, activity metrics could include outreach and in-reach efforts by an ORTA (such as training sessions provided or number of contacts made with industry), or patent applications filed, among others.
- *Output metrics* are measures of the "direct production of agency activities and efforts" (Jaffe 1998). In the context of technology transfer that leads to commercialization, examples could be license agreements signed, start-up companies formed, among others.
- *Outcome metrics* describe "the effects or consequences that the program is intended to have" (Jaffe 1998). Outcomes could be license revenue or additional

[36] For example, if an ORTA uses licensing income as a metric of success, the ORTA may focus solely on achieving high revenue deals as opposed to encouraging start-ups or other activities that, while are potentially more valuable activities, are likely to have a lower licensing revenue in the short-term than would licensing to an established company.

funding received by a start-up based on a laboratory technology (as a measure of its progress), among others.

- *Broader impact metrics* are often also included when describing a program. These impacts are influenced by a number of factors beyond the control of the program, describe changes beyond the scope of the program, and cannot be directly attributable to a program. In this context, broader impacts could include commercialization revenue, economic growth of the region, improving the technological capacity of the nation, or other larger scale changes.

Metrics within the above categories can further be described as follows:

- Metrics can be either quantitative or qualitative.
- Count metrics are based on raw counts of parameters of interest.
- Efficiency metrics are based on ratios of program outputs or outcomes to program inputs.
- Effectiveness metrics are based on comparing the outputs or outcomes of a program to its stated goals for outputs and outcomes.
- Leading metrics are indicators of future developments; lagging metrics are those that look at past developments.

2. Aligning Metrics with Goals

While an abundance of metrics could be developed around technology transfer at the federal laboratories, there is a cost associated with collecting data. The decision must be made as to which are most important and feasible to collect.

The relative importance of collecting each metric can be structured by first defining the program's goals and then determining how those goals are best measured. Those will form the outcome metrics, and the inputs, activities, and outputs expected to be needed to achieve those outcomes should follow logically.[37] Although this first step may appear straightforward, it is not an easy task, both because of the multivariate nature of goals, and because there can be several different stakeholders involved who have differing definitions of success.

One source in which to look for statements of goals for technology transfer that leads to commercialization is the legislation that requires the laboratories to engage in

[37] There is more to the process of developing robust metrics than is implied here. Metrics should be defined and tested, and the data collected should be checked for quality.

technology transfer. The goals of technology transfer from the laboratories are, as defined in the Stevenson-Wydler Act as amended (15 U.S.C. § 3702):

> to improve the economic, environmental, and social well-being of the United States by…stimulating improved utilization of federally funded technology developments, including inventions, software, and training technologies [and]…encouraging the exchange of scientific and technical personnel among academia, industry, and federal laboratories.

These goals can be met by federal laboratories in a variety of ways. Does a laboratory improve the economic well-being of the United States by creating start-up companies, by providing standards upon which industry may work, or by other means? If more than one, what is the relative importance of each activity? How best to realize the outcomes set forth in Stevenson-Wydler depends on the structure of the industry with which the laboratory collaborates, the role of the laboratory relative to other R&D performers, the geographic location of the laboratory, and many other factors.

Agencies have different missions and are accountable to different stakeholders, who may have differing opinions about how best to achieve those outcomes set forth in Stevenson-Wydler. Technology transfer is just one of several activities that the federal laboratories have been tasked to do. Related to this, metrics that track technology transfer that leads to commercialization do not necessarily indicate fulfillment of laboratory mission. Rather, these metrics are a subset of indicators that may or may not correlate with the overall goal of a laboratory's research mission. Metrics that are solely related to commercialization will inherently undervalue those laboratories whose missions are not as well-aligned with commercializing technology.

The next section discusses how metrics are collected and currently used, and explores the related issues of measuring and managing technology transfer from the laboratories at three different levels: government-wide, agency-wide, and at an individual laboratory.

B. Measuring Success Government-Wide

1. Defining Success

Reporting on laboratory performance relative to technology transfer has been required since the Federal Technology Transfer Act of 1986, when the Stevenson-Wydler Act was amended to add a requirement for the preparation of a Biennial Report on government-wide federal laboratory technology transfer activities. The Biennial Report was produced by the Office of Technology Policy in the DOC's Technology Administration (TA) from 1989 to 2001. In 2000, the existing Biennial Report process was significantly revised by the Technology Transfer Commercialization Act of 2000 (TTCA) (P.L. 106-404). Provisions of the TTCA replaced the Biennial Report with a statutory annual performance report on technology transfer activities and achievements as part of the agency/department annual budget proposal. The TTCA also mandated that the Secretary of Commerce summarize all the agency data in the annual summary report to the President and Congress. The TTCA stated that agencies should include (15 U.S.C. §3710(f)):[38]

> …an explanation of the agency's technology transfer program for the preceding fiscal year and the agency's plans for conducting its technology transfer function, including its plans for securing intellectual property rights in laboratory innovations with commercial promise and plans for managing its intellectual property so as to advance the agency's mission and benefit the competitiveness of United States industry; and
>
> (B) information on technology transfer activities for the preceding fiscal year, including—
>
> > (i) the number of patent applications filed;
> >
> > (ii) the number of patents received;
> >
> > (iii) the number of fully-executed licenses which received royalty income in the preceding fiscal year, categorized by whether they are exclusive, partially exclusive, or non-exclusive, and the time elapsed from the date on which the license was requested by the licensee in writing to the date the license was executed;
> >
> > (iv) the total earned royalty income including such statistical information as the total earned royalty income, of the top 1 percent, 5 percent, and 20 percent of the licenses, the range of royalty income, and the median, except where disclosure of such information would reveal the amount of royalty income associated with an individual license or licensee;
> >
> > (v) what disposition was made of the income described in clause (iv);
> >
> > (vi) the number of licenses terminated for cause; and
> >
> > (vii) any other parameters or discussion that the agency deems relevant or unique to its practice of technology transfer.

The DOC's Technology Administration and the principal affected agencies worked through the longstanding Interagency Working Group on Technology Transfer (IWGTT) between 2001 and 2003 to agree on common definitions, metrics, data, and report content. These agreements formed the basis for the individual agency reports in FYs 2001, 2002, and 2003 and the corresponding summary reports by the Secretary of Commerce (U.S. Department of Commerce 2004). The Office of Management and

[38] The metrics reported in the summary report primarily represent technology transfer that leads to commercialization, and not those activities in the indirect pathway discussed in Chapter 2, such as publications and students trained.

Budget (OMB) formally incorporated these TA/IWGTT guidelines in its annual Circular A-11 guidelines for annual budget preparation starting in July 2003 (OMB 2010). With the termination of Commerce TA and the Under Secretary for Technology in August 2007, responsibility was delegated to NIST's Office of Technology Partnerships for preparing the summary reports and related processes. The present reporting remains largely consistent with the 2003 TA/IWGTT guidelines. According to interviews with stakeholders, with the current focus on innovation and commercialization, there has been renewed interest within the IWGTT and other White House working groups in examining additional metrics that may better reflect those priorities.

The reporting of metrics on technology transfer from the laboratories was a responsibility of the Technology Administration office, abolished in 2007. NIST was given the responsibility of reporting.

2. Metrics in the Summary Report

The annual summary report to the President and Congress on technology transfer at the federal laboratories exclusively presents count metrics at the agency level. Data reported at the agency level are (NIST 2010):

- Number of active CRADAs (new, traditional, nontraditional, and other)
- Number of invention disclosures, patent applications, and patents issued
- Number of licenses (invention, and other intellectual property; total active and new)
- Number of income-bearing licenses (total and exclusive)
- License income (invention, other intellectual property, earned royalty income)

The metrics do not facilitate comparisons across agencies. Not all measures for the specific technology transfer authorities of each agency are included. Finally, because these are count metrics rather than efficiency metrics, the reader is not provided any context regarding the differing size of agencies' laboratories and other inputs. This makes it challenging to understand the types of activities that agencies are engaging in (e.g., there is no report of "research partnerships with industry" to capture all types of partnerships regardless of the legal agreement used).

The current metrics as provided in the summary report exclusively present count metrics at the agency level and cannot be used to facilitate comparisons *across agencies.*

There are also questions of data quality in the report. A 2009 U.S. Government Accountability Office (GAO) report on how the DOE laboratories define and measure success in technology transfer found inconsistencies in what the laboratories reported to the agency for publication in the annual report and the data that the laboratories had on hand when audited by GAO (GAO 2009).

The National Academy of Public Administration (NAPA) study of technology transfer from NASA presented efficiency metrics for NASA's laboratories, and compared them to select universities (NAPA 2004). Although the diversity of the federal laboratories cautions one against comparisons, normalizations can be useful to better assess the outputs of a federal laboratory or agency with respect to their overall scope of R&D inputs.

3. Stakeholders' Assessment of the Summary Report

Many of the agency-level technology transfer office and laboratory ORTA personnel interviewed felt the metrics contained in the summary report did not fully capture their laboratories' technology transfer activities, outputs, and outcomes. On the other hand, some acknowledged that the report is useful for periodic data calls from agency leadership or Congress on their technology transfer activities and outputs.

Interviewees believe the metrics in the annual report do not reflect the diverse types of technology transfer that leads to commercialization occurring at the laboratories.

4. How Summary Report Metrics May Be Used

The Technology Transfer and Commercialization Act outlines what the report from the agencies to OMB shall include, as was discussed in section C.1 previously in this chapter. The act also sets parameters for the aggregated report across all agencies. It shall (15 U.S.C. §3710(g)(2)(B)):

> (i) draw upon the reports prepared by the agencies under subsection (f);
>
> (ii) discuss technology transfer best practices and effective approaches in the licensing and transfer of technology in the context of the agencies' missions; and
>
> (iii) discuss the progress made toward development of additional useful measures of the outcomes of technology transfer programs of Federal agencies.

This does not provide insight into how Congress intended the report to be used by itself, the White House, and the U.S. Trade Representative. We provide possibilities for uses of the report and analyze whether the report as it stands currently is likely to meet those needs.

Is the report to be used as a clear description of technology transfer occurring across the government laboratories? If so, there should be metrics to reflect the laboratory missions. Furthermore, descriptions of the role that technology transfer plays in achieving agency missions are brief.

Is the report to be used as a measure of the effort devoted by agencies and laboratories in support of technology transfer that leads to commercialization? If so, it is insufficient. Measures of the FTEs devoted to technology transfer or sums of funds devoted to technology transfer and commercialization activities, or similar types of measures are not provided in the report.

Is the report to be used as a measure of the implementation of the Stevenson-Wydler Act and subsequent legislation? If so, it is insufficient. The annual report does not contain information on how agencies are implementing specific requirements of Stevenson-Wydler, such as the royalties provided to inventors, or how technology transfer is being used in performance reviews, or other similar measures.

The annual report does provide an annual snapshot of the output of the federal laboratories. Minimal changes to the report have been made in the amendments to the technology transfer legislation, suggesting that the report is serving its intended purpose.

It is beyond the scope of the report to assess how Congress, the President, and the U.S. Trade Representative, or others use the summary report and whether they find it sufficient for those uses. It is evident, however, enhancements would be required for it to address many questions regarding technology transfer that leads to commercialization at the federal laboratories.

C. Measuring Success Agency-Wide

1. Defining Success

As discussed above, each agency must submit information on its technology transfer plans to OMB as part of its annual budget submission. The summary report discussed above is a synopsis of data provided as a part of that submission. It is likely, however, that agencies will have a different definition of success than is embodied in the metrics collected in the summary report, due to their diverse missions and authorities.

2. Metrics Currently Used

As part of this study, agency-level technology transfer office staff members were asked which metrics are collected in addition to those required in the summary report. Some agencies did not collect more metrics than required, while others used a considerable number of additional metrics. Appendix G contains a list describing some of the supplementary metrics laboratories and agencies collect

3. How Technology Transfer Metrics May Be Used

The technology transfer metrics collected by an agency could be used in several different ways.

The metrics could be used to understand trends in performance of various laboratories. A coordinator may also wish to know the resources devoted to technology transfer, and could look to input metrics for this information. However, based on conversations with agency-level technology transfer office and laboratory ORTA personnel, it appears that formal mechanisms for oversight of technology transfer activities are not currently in place. Generally, agencies do not provide feedback to the laboratories as to their technology transfer performance.

Agency leadership might wish to know the portfolio of outputs and outcomes resulting from the agency's laboratories. Metrics could be used to understand where there may be gaps with respect to achieving the agency mission.

Agency leadership may also wish to have a clear understanding of what they hope to accomplish with respect to technology transfer so that they may present their plans for the future fiscal year during their annual budget submission. This understanding will also likely be of use during interactions with Congress.

Based on conversations with agency-level technology transfer representatives, it appears that some agencies use metrics to understand trends at the laboratories, but for the most part, the potential applications of metrics are not fully realized.

The use of metrics at the agency level to oversee and assess technology transfer at the laboratories appears to be rare.

D. Measuring Success at a Laboratory

1. Defining Success

From the discussions with laboratory ORTA staff, we found that they do not have a singular definition of success. Given the diversity of the laboratories, this is not unexpected. In most cases, however, laboratory ORTAs could not articulate what their laboratory's overarching goals are with respect to technology transfer that leads to commercialization. This is consistent with the 2009 GAO Report on the DOE laboratories, where it was found that the "DOE cannot not determine the effectiveness of technology transfer at its laboratories because it has no overarching goals or reliable performance data" (GAO 2009).

According to the ORTA personnel, one of the reasons for their difficulty in defining success is that they feel as if they have multiple, often competing, goals provided by laboratory and agency management. For example, some stakeholders may want the ORTA to be more aggressive in finding industry partners, while their general counsel may want the ORTA to be more conservative. Or the ORTA may feel pressure to not license a technology and instead use it as an incentive to find a CRADA partner, while others would prefer it were licensed directly. Partially due to these conflicts, the ORTA members are unclear as to how to define success.

Laboratories have unique missions and define success with respect to technology transfer differently. Most laboratory ORTA personnel could not provide a clear definition of what success means to their laboratories. Without this definition, laboratories are unable to measure whether they are accomplishing their goals.

2. Metrics Currently Used

As previously mentioned, measures in the summary report are presented at the agency level as opposed to the individual laboratory level. It is impossible to conduct any laboratory-level analysis of technology transfer and commercialization using the data from the summary report. Some laboratories create rather detailed annual reports, but the measures are not standardized or compiled in any single source. Based on our discussions, we conclude that the collection of metrics varies considerably from agency to agency and from laboratory to laboratory.

Many laboratories already collect additional metrics beyond what is required by the summary report. Two illustrative examples follow:

- ARS collects Material Transfer Agreements (MTAs) separated as incoming (for the purpose of bringing materials into the laboratory) and outgoing (for the purposes of sending material outside of the laboratory). ARS technology transfer personnel stated that outgoing MTAs are critical because they indicate that someone finds the invention useful. ARS reported that it performs roughly 900 MTAs per year, with 600 of those being outgoing, covering internal materials going from the laboratory to outside industry partners.
- Another laboratory evaluates its success on the basis of the amount of funds received for CRADAs, number of agreements, number of return customers, and year-over-year revenue increase.

STPI asked some laboratory ORTA staff to provide the actual data, but laboratories were reluctant to divulge such information.

Data on outputs and outcomes at the laboratory level are not available, except for selected metrics that appear in annual reports.

Many ORTA interviewees at the laboratory level reported that success stories provide the most accurate description of the results of technology transfer at their institutions. They asserted that these stories carry the most impact when arguing for the benefits of technology transfer because, as one put it, “stories stick.” Furthermore, quantifying the positive aspects of technology transfer or commercialization may be difficult as many of the most important outcomes (e.g., job creation) happen downstream.

As one ORTA representative noted, "Metrics are not the best reflection; they are output oriented and based on decades-old definitions. PART and GPRA measure impact, and since we don't do that in [technology transfer], we do anecdotes."

3. How Technology Transfer Metrics May Be Used

There is a variety of possible uses of metrics at the individual laboratory level.

Laboratory directors may wish to know how effective their ORTAs are at performing technology transfer that is consistent with the laboratory's mission. Leadership could be interested in outputs and outcomes that describe the impact of the laboratory's technology transfer. Most of the ORTAs interviewed did not feel as if the laboratory director had a clear articulation of how technology transfer fit into achieving the laboratory's mission.

Laboratory directors may also be interested in knowing about the "return on investment" of their technology transfer function. If the laboratory ORTA is substantially funded and staffed, but shows little output, the laboratory director may be interested in exploring what problems may exist within the ORTA.

Laboratory ORTA directors may be interested in their own processes and understanding what leads to effective collaborating and licensing. They may be interested in activity and efficiency metrics to manage their internal processes. Some laboratory ORTAs appear to be collecting these types of metrics, although the majority of laboratories are not.

Some of the DOE laboratories stated they receive support through state and local governments to provide technical assistance to small businesses. State and local governments may wish to know how a specific laboratory is contributing to the local economic ecosystem. A clear articulation of the expected outputs and outcomes of the laboratory, whether that is through scientific dissemination, human capital, or other more traditional technology transfer outputs, can help convey this information to these stakeholders.

Laboratory-level metrics can serve a variety of purposes. Interviewees stated that while outputs and outcomes are often the most sought metrics, they can be difficult to attribute to a laboratory, expensive to collect, and may not reflect the success of a laboratory's technology transfer program. Activity and process metrics can be, but appear to be rarely, used to measure and manage a laboratory ORTA's processes.

E. Additional Metrics

1. Possible Additional Metrics Suggested by Laboratory ORTAs

Laboratory ORTA personnel discussed possible additional metrics that they either do collect and would be willing to report on or would like to collect. These metrics are not currently collected by the majority of laboratory ORTAs, yet the fact that they are measured by some demonstrates their feasibility. It is possible additional laboratories could begin collecting these metrics.

Some activity metrics included:

- Number of seminars and training sessions for researchers[39]
- Number of researchers who contact or are contacted by the ORTA
- Number of times the ORTA contacted industry or was contacted by industry
- Researcher and industry satisfaction measures

Some laboratories stated that simply knowing how long something takes provides sufficient incentives to speed it up. Some process efficiency metrics included:

- Time between the first invention disclosure and the point of licensing a technology. Even though some of this process is dependent on the USPTO's timeline, one laboratory ORTA that measured this said that by measuring and managing this process, the time to do so dropped from 2,000 to 1,000 days.
- Time to process sponsored research agreements.

Some ORTAs collect additional output and outcome metrics:

- Number of start-up companies formed around technologies licensed from the laboratory
- Number or value of commercialized technologies (or technologies in the product development pipeline)

Broader impact measures are harder to define and measure, yet some laboratories had performed economic impact studies (see box).

[39] One ORTA representative noted that valuable research time should not be taken by training that is not fruitful. The representative proposed providing core training and then using the latest IT tools to make information readily available for those who forget things they learned but rarely use.

Economic Impact Studies

The full impact of a program is typically the most desired, and the most challenging, aspect to measure. Economic impact studies have been used to provide quantitative estimates of the economic effects of a given program. They typically do so by calculating the level of economic activity that exists in the presence of the program and subtracting the level of activity that would be expected if the program did not exist.

The advantages of an economic impact study are that it captures the outcomes and impacts of a program, and they are especially appropriate in the context of programs whose goals are to increase economic growth. Some disadvantages are that the studies can be quite expensive to perform, and must be done in a methodologically rigorous manner to allow for analytical results.

The Department of the Navy's Technology Transfer Program recently sponsored an economic impact study of 100 technology transfer agreements (CRADAs and Patent License Agreements). Using commercially available input-output modeling system software, the Navy-sponsored research team found that the 100 technology transfer agreements were responsible for 670 jobs and $200 million of direct economic effect. Further information on the study can be found in the report provided at http://www.ibrc.indiana.edu/studies/t2.pdf.

Other laboratories, such as Lawrence Berkeley National Laboratory, have commissioned economic impact studies of their laboratories as a whole, with technology transfer-specific impact measured as a part of the studies.

As another example of economic impact, the National Institutes of Health's Office of Technology Transfer reported combined sales on products under NIH licenses was nearly $6 billion in FY 2010.

2. Possible Additional Metrics Suggested by University and Other Organizations

The topic of developing appropriate metrics to measure activities, outputs, and outcomes is not unique to the federal laboratories. There have been several ongoing efforts to develop appropriate metrics to describe technology transfer, including those undertaken by the Association of University Technology Managers (AUTM) and the Association of Public and Land-Grant Universities (APLU). Some stakeholders additionally provided examples of the metrics that they suggest using as measures for describing technology transfer and commercialization.

Many of the suggested metrics were process metrics. Stakeholders recognized that these are somewhat less satisfying to report on, as outputs and outcomes are typically considered more important indicators of success. However, as has been discussed before, the commercialization process is long and highly complex. Metrics that can anticipate and plan for these outcomes that reflect the activities that lead to these outputs and outcomes are typically not considered. Some stakeholders also highlighted the theories of W. Edwards Deming and others who have studied industrial processes. Deming's school of thought argues that focusing on improving the activities and processes will lead to an improvement in outcomes.[40] Examples of activity metrics suggested included:

- Number of researchers who request meetings with ORTA staff
- Number of meetings with entrepreneurs and companies

The Association of University Technology Managers (AUTM), the professional society for technology transfer professionals working at universities, holds an annual survey to collect data on university technology transfer activities and outputs. The metrics collected by AUTM include:

- *Inputs:* Technology Transfer Program Start Date; Staff Size (both Licensing FTEs and Other FTEs); Institutional Research Expenditures; Invention Disclosures (by research area)
- *Activities:* Patent Applications Filed
- *Outputs:* Licenses Executed (to Start-ups, to Small Companies to Large Companies); Number of Start-ups*;* Source of Funding for Start-ups
- *Outcomes:* Royalties Earned*;* Licensed Technologies Available for Consumer or Commercial Use

AUTM provides access to the collected historical data through a searchable and exportable database. AUTM is also developing additional metrics (see box).

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[40] For more information on W. Edwards Deming, see http://deming.org/.

Efforts to Develop Additional Metrics

Association of University Technology Managers (AUTM)

Universities are interested in understanding how to better describe the role that universities and university technology transfer play in promoting economic development. As the major source for metrics describing university technology transfer, AUTM has been involved in developing new metrics to better describe technology transfer activities, outputs, and outcomes specific to local economic health. AUTM has published a draft proposal for metrics that describe how an institution has an impact on its community and local economy. Metrics are proposed in a variety of thematic areas, including:

- Institutional Support for Entrepreneurship and Economic Development
- Ecosystem of Institution
- Human Transfer Activities
- Technology Knowledge Transfer Activities
- Network Creation Activities
- Value Creation Activities

AUTM stresses that final economic impacts are created by partners of the universities and not the universities themselves, and that the direct influence of the university should not be overstated given the variety of factors that affect a technology or knowledge once they have left the university. Likewise, because of the complexity of the system, AUTM suggests that several measures are needed to fully capture the elements of the system. The draft proposal, AUTM's Proposal for an Institutional Economic Engagement Index, can be found at: http://www.autm.net/AM/Template.cfm?Section=New_Metrics&Template=/CM/ContentDisplay.cfm&ContentID=4059.

Association of Public and Land-Grant Universities (APLU)

APLU's Commission on Innovation, Competitiveness and Economic Prosperity held an NSF-sponsored workshop in February 2010 to identify potential new metrics of universities' contributions to regional economics, with the goal of identifying 4-6 measures that could be examined by NSF for inclusion in their Higher Education Research and Development (HERD) Survey. Attendees of the workshop included representatives from academia, industry, government, non-profit organizations, and the media, who gave their feedback in three discussions centered on Linkages and Partnerships, Entrepreneurship, and Human Capital.

According to stakeholders, the discussion was robust yet consensus was not achieved during the day-long session. Thus, following the workshop, APLU surveyed the attendees to see which indicators were considered most important for an institution's role in regional economic development. The five highest scoring indicators were:

- Progress over time of companies started with university IP (measured via investment capital raised; payroll taxes paid; new markets accessed)
- Faculty/staff consulting with industry with a focus on consulting that is assisting development of firms
- Alumni employment paths/progress
- University investments in technology transfer/commercialization operations
- Impacts of university research and technical or technological assistance

As has been stressed in this report for the federal laboratories, APLU also urged NSF to consider factors that could affect the measurement of these contributions. These factors include institutional context, environmental or external context, normalizing data across institutions, and using self-reported systems or other data sources that already exist.

The APLU report to NSF can be found at: http://www.aplu.org/NetCommunity/Document.Doc?id=2777.

APLU is continuing to work to develop a survey of its members to begin to collect metrics, and is also promoting the use by its members of an Institutional Self Assessment Tool (http://www.aplu.org/NetCommunity/Page.aspx?pid=1490) in the hopes that institutions can develop metrics that best describe their contributions to regional economic growth, given the unique factors present at each institution.

3. Challenges to Collecting Additional Metrics

While there is an interest in collecting metrics that better measure the impact of technology transfer that leads to commercialization, there is an associated burden and relative pay-off from doing this. Collection of data may be overly burdensome and ultimately counterproductive if it diverts limited ORTA resources and personnel away from partnering, patenting, and licensing. This is especially true for the smaller ORTAs.

Technology transfer that leads to commercialization may be peripheral to the laboratory's mission and therefore additional commercialization metrics would not accurately describe mission fulfillment. One ORTA representative at a GOCO said although technology transfer is designated as part of their mission in the contract, it is not the main mission, which sometimes makes it a challenge to collect the necessary resources to make technology transfer a success. While technology transfer is valuable to the success of their laboratory, she asserted it is not critical.

It will be difficult for many laboratories to collect additional metrics because they lack dedicated personnel and resources or data infrastructure. For example, one ORTA interviewee reported that they had just updated their data collection system from WordPerfect to a spreadsheet.

On the other hand, some agencies and laboratories have already developed relatively sophisticated databases and requiring additional reporting of metrics that they already collect would not be particularly burdensome. NIH's Office of Technology Transfer introduced an integrated database in 2003, TechTracS, which was first developed at NASA, and now is provided by a commercial provider, Knowledge Sharing Systems.[41] NIH modified TechTracS to meet internal needs, and it manages monitoring and enforcement of patents, and licenses and CRADAs, among other things.

There are some developments outside of the federal laboratories, however, that show there may be ways to report on data originally collected for other purposes. One example of this is the STAR METRICS initiative spearheaded by NSF, NIH, and others in the federal government.

Additional metrics could be used to report on technology transfer inputs, activities, outputs, and outcomes, although each has an associated cost of reporting. Before additional metrics are considered, one should specify the purpose of using the metrics, who is going to use them, and which metrics are the most important to gather.

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[41] For more information on Knowledge Sharing Systems, see http://www.knowledgesharing.com/about.htm.

F. Summary and Implications

The development of appropriate metrics depends on a clear statement of a program's desired outputs and outcomes, and metrics can be used for a variety of purposes. Because of the diversity of goals across the federal agencies and laboratories, it is difficult to come up with a single set of metrics for the entire portfolio of federal laboratories. Different stakeholders have an interest in metrics on technology transfer that leads to commercialization from the laboratories, and it is not clear that the currently collected metrics meet the needs of all those stakeholders.

We also note that data on performance at the level of individual laboratories are unavailable. This had repercussions for this study, as the factors interviewees stated are important cannot be correlated to an independent analysis of "success" at the laboratories.

7. Strategies to Increase the Speed and Dissemination of Technology Transfer that Leads to Commercialization

Chapter 5 highlighted the factors that affect the speed and dissemination of technology transfer from the federal laboratories that leads to commercialization. The factors are in many cases stated as the barriers that laboratories face. Our interviews with ORTA representatives also revealed strategies that agencies and laboratories are undertaking that they believe help eliminate or at least alleviate those barriers, to increase the speed and extent of dissemination of technologies. This chapter delineates those strategies, which were interspersed throughout Chapter 6, and includes possible other strategies suggested by interviewees.

Some of these strategies could be adopted by ORTAs in other laboratories or agencies without requiring additional resources. Other strategies would require allocation of resources.

Again, these strategies were suggested by ORTA representatives and other stakeholders we interviewed, and their effectiveness has not been assessed. Given the diversity of the federal laboratories, each strategy must be examined in the context of the laboratory in question and, if adopted, adjusted based on the unique needs and strengths of that laboratory.

A. Laboratory Mission, Laboratory Management, and Congressional Support and Oversight

These three factors—mission, management, and congressional support and oversight—are grouped together as they fall outside the scope of strategies that the laboratories themselves are able to control. However, we include here some suggestions made by interviewees that may serve as topics for future study or consideration by policy makers.

The alignment between laboratory mission and technology transfer that leads to commercialization was found to be a factor that affected the speed and dissemination of technology transfer. How technology transfer, specifically technology transfer that leads to commercialization, fits into achieving the laboratory mission is often not explicitly stated. Stakeholders suggested that laboratory directors and agency leadership could work with ORTAs to articulate how technology transfer fits into achieving the laboratory mission, and that this articulation could serve as the basis for setting forth a strategic plan for the ORTA. Other stakeholders suggested that laboratories not expected to perform much technology transfer that leads to commercialization due to their mission and the nature of their research may consider engaging in technology transfer activities operated at a regional level. This would allow for economies of scale on technology transfer processes.

Laboratory management affects technology transfer that leads to commercialization, but, like laboratory mission, is also something that the laboratories themselves do not have control over. Nonetheless, interviewees stated that it might be useful for policy-makers to assess the differences between the authorities and guidelines given to GOGO laboratories and GOCO laboratories and assess whether there are authorities that should be extended to GOGO laboratories. Furthermore, some laboratories are using novel arrangements with universities to provide greater flexibility for their researchers to partake in technology transfer activities.

Likewise, congressional support and oversight falls outside the scope of laboratory strategies, yet interviewees stated the articulation suggested above might also be of use in conveying to Congress the nature of technology transfer at the federal laboratories.

B. Agency Leadership and Laboratory Director Support

Strategy for increasing agency leadership and laboratory director support:

- Educate laboratory directors about the importance of technology transfer for achieving the laboratory mission.

C. Organization and Coordination of Technology Transfer and Commercialization Activities

Strategies for increasing coordination across laboratories:

- Appoint a technology transfer coordinator that ensures that agency policies are understood and implemented uniformly.
- Hold agency-specific technology transfer working group meetings at FLC meetings or on their own.

Strategy for increasing visibility of technology transfer and commercialization at laboratories:

- Locate the ORTA at a position within the laboratory or agency where it has visibility to the entire organization.

D. Offices of Research and Technology Applications

Strategies for enhancing the expertise of ORTAs:

- Provide training and instruction. Several staff members had participated in these training programs, either receiving the training themselves, or serving as instructors. Technology transfer instruction is provided agency-wide by the Federal Laboratory Consortium for Technology Transfer and the Office of Personnel Management (OPM), at individual agencies, and through undergraduate and graduate level classes and programs at universities. Laboratories and agencies can offer trainings related to business interactions and technology transfer that leads to commercialization for researchers to attend.
- Hire ORTA staff with specific expertise in marketing, business development, and experience in forming start-up ventures.

Strategy for focusing on technology commercialization:

- Streamline the administrative aspects of technology transfer to allow staff to focus on the technology commercialization aspects at ORTAs.

Strategies for streamlining and reducing administrative processes:

- Use electronic agreements to reduce paperwork and the administrative burden. For example, one laboratory uses a single email for Material Transfer Agreements, rather than countersigned paper contracts that must be faxed three times.
- Automate royalty payments. The National Institutes of Health (NIH) is using pay.gov to receive royalty payments, reducing the time for payment from multiple months down to less than a day.
- Determine systematically which inventions should be patented or further developed. Laboratories that manage a large intellectual property portfolio often employ such strategies. At one laboratory, even before the invention evaluation committee meets, inventions are typically first assessed by people with medical, legal, and business experience to get a sense of the patentability and marketability of the technology. Other laboratories performed a market analysis prior to making patent decisions. Still others use invention evaluation committees that review all inventions and make recommendations to the ORTAs as to which should be patented, which should not, and which may require further work before a decision can be made.
- Conduct process studies. ORTAs can conduct process studies (such as Six Sigma) and use the results to eliminate unnecessary steps and to improve their administrative processes.

Strategy for using legal mechanisms in novel ways:

- Modify existing mechanisms. For example, the Department of Energy (DOE), Department of Defense (DOD), and NIH authorize their laboratories to use master CRADAs that allow for a single negotiation for several different projects with an industry partner. The NIH has developed a "Research Collaboration Agreement," which is essentially a Material Transfer Agreement plus aspects of a CRADA, but only for those research projects under which no funds would be received or exchanged and when the collaborator is not granted a license or rights to license new technologies. The Department of Homeland Security (DHS) has developed a "Secure CRADA" under which it will test technologies developed by industry. This CRADA has shortened agreement language.

Strategy for receiving outside advice:

- Use advisory committees. Some of the federal laboratories have advisory committees that provide guidance for improving commercialization processes and serve as a source of commercialization expertise. For example, the DOE National Renewable Energy Laboratory (NREL) Venture Capital Advisory Board meets quarterly. This board provides insight into how the ORTA is operating and reviews the feasibility of NREL's technology maturation fund proposals.

E. Researchers

Strategy for increasing the education and engagement of researchers:

- Conduct "in-reach" activities. Several ORTA staff stressed the importance of "in-reach" to researchers to explain their importance in the technology transfer process. For example, training scientists in entrepreneurship topics was done at several laboratories. This is either done through a third party, such as a partnership intermediary, through an affiliated business school or university, or by the ORTA staff themselves.

Strategies for increasing the incentives for researchers to engage in technology transfer and commercialization:

- Provide mechanisms for researchers to charge time to technology transfer activities. If the accounting system of a laboratory requires researchers to charge each hour of their time to a project, researchers will be unable to work on technology transfer activities unless it fits within an existing project. Some stakeholders suggested that this issue could be resolved by having "technology transfer" or "business development" charge codes within a laboratory.
- Institute entrepreneurial leave policies. Several DOE GOCO laboratories have entrepreneurial leave policies. For example, Sandia National Laboratories has

established the Entrepreneurial Separation to Transfer Technology (ESTT) program that allows employees to leave to start a company. Reinstatement is guaranteed if the researcher returns within two years or researchers can request an extension for a third year. There are some issues with the programs, however, that are currently being examined by the laboratories employing the programs.

- Reward researchers for excellent work related to technology transfer that leads to commercialization. For example, Pacific Northwest National Laboratory (PNNL) hosts a formal annual awards ceremony, which the laboratory director attends. Researchers at PNNL can earn the "Top Inventor of the Year" award, as well as the title of "Distinguished Inventor" if they hold 15 or more patents.
- Provide cash incentives. Some laboratories provide cash awards of several hundreds or even thousands of dollars for invention disclosures, patent applications and patent issuance. For example,
  - Naval Surface Warfare Center Crane Division (NSWC-Crane) offers a $15,000 award to the scientists with the top three patents of the year. Cash awards for inventions and the patent approval process range from $200 to $500.
  - USDA offers annual cash awards (two for $4,000 and up to six for $3,000) to individuals or groups who have undertaken creative technology transfer in the past 3 years that has had impact. They honor one person with a Sustained Effort Technology Transfer Award to recognize research outcomes that have multiple stages of technology transfer over longer periods of time (development time 5 to 15 years). The amount of the award is $4,000.
- Offer higher royalties for patents. Some laboratories offer larger royalties to inventors of patents. The percentages of royalties given to researchers ranged from the minimum 15 percent up to 40 percent in at least one laboratory.
- Include technology transfer that leads to commercialization in researchers' performance evaluations. Lawrence Livermore National Laboratory (LLNL) treats patents at the same level as publications for performance evaluation purposes.

F. Government-Industry Interactions

Strategies to augment visibility and access to federal laboratories as well as improve government-industry interactions:

- Conduct technology showcases. Several laboratories have developed technology showcases that attempt to reach out to companies that are unfamiliar with the federal laboratories. For example, the NIH has participated in technology showcases sponsored by FLC Mid-Atlantic region and Maryland TEDCO, among others, to highlight available technologies. The Office of Naval Research (ONR) hosts the Navy Opportunity Forum, an annual event that allows companies to become aware of laboratory technologies that could be developed through Small Business Innovation Research (SBIR) Phase I and II proposals.
- Develop an intellectual property (IP) database. Several technology transfer staff voiced the need for a unified IP database that would alert industry to laboratory technologies.
  - The partnership intermediary TechComm is working on integrating the internal databases of several agencies and laboratories onto a central server.
  - Several laboratories have developed databases to promote their available IP to interested industry partners. For example, DOE's Office of Energy Efficiency and Renewable Energy developed a searchable website listing the energy-related technologies of nine DOE laboratories. The Energy Innovation Portal allows users to search several thousand patents and patent applications as well as several hundred technology marketing summaries. The NIH and Food and Drug Administration (FDA) offer website**s** that list many available NIH and FDA technologies and provide the ability to register for a RSS feed of available technologies and technology updates.
- Encourage professional networking. In order to overcome the lack of visibility, many ORTA staff stated they spend time networking at conferences and workshops.
- Develop policies that are workable for industry partners. For example, recognizing that small businesses would rarely have the resources to be able to purchase liability insurance or indemnify the government and the fact that the government's liability is limited under the Federal Tort Claims Act,[42] the U.S. Department of Agriculture (USDA) worked with counsel to remove these provisions from its partnership agreements.

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[42] For a discussion of the limitations of government liability under the Federal Tort Claims Act, see Cohen and Burrows (2007), available at http://www.fas.org/sgp/crs/misc/95-717.pdf.

- Secure copyright protections. Some GOGO laboratories have found creative ways to assert copyright protection. For example, one laboratory ORTA employee explained that the laboratory obtains copyrights for software by asking the industry partner to assert the rights to the intellectual property, and then assign those rights to the laboratory.
- Use formal or informal partnership intermediaries to bridge the differences between laboratories and industry. Partnership intermediaries or Partnership Intermediary Agreements (PIAs) exist to help laboratories navigate the technology development and commercialization processes. These PIAs often undertake functions that the laboratory either cannot do or is not well suited to do.

G. Resources

Strategies to increase the availability of resources for technology transfer that leads to commercialization:

- Provide funding to develop technologies further before transfer. Many of the technologies invented at the laboratory are at an early stage and require further development before they can be transferred to industry. The EERE office within the DOE developed a fund that administers $14 million for technology maturation of technologies related to energy efficiency and renewable energy.
- Use partnership intermediaries as a source for technology maturation funds. The DOD has established a PIA, MilTech, that specializes in producing physical prototypes. Maryland TEDCO recently established a technology maturation program known as the Joint Technology Transfer Initiative (JTTI) that awards grants of up to $75,000 for technologies that are either spin-in or spin-out of the DHS or the U.S. Army Medical Research and Materiel Command (AMRMC).
- Federal laboratories could leverage local, state, and federal commercialization programs. For example, the National Institute of Standards and Technology (NIST) SBIR Technology Transfer (SBIR-TT) program is using SBIR funds to develop technologies further that were initially created at the laboratories. Other federal technology transfer programs are now adopting SBIR-TT.

H. Summary

This chapter lists the strategies and suggestions heard in interviews provided by stakeholders. These are not intended to be recommendations; we stress again that the effectiveness of these strategies was not assessed. Instead, these are strategies that interviewees believed increased the speed and extent of dissemination of technology transfer that leads to commercialization.

8. Summary and Conclusion

This landscape study describes the technology transfer and commercialization activities, barriers, and current measures of success at federal laboratories. It provides a snapshot of conditions at the federal laboratories for technology transfer that leads to commercialization. It is the first systematic study of technology transfer at federal laboratories published since the early 2000s. This study covers a larger number of diverse laboratories than the previous studies.

Identification of areas for future study was part of the study's charge. Many of the study team's findings from discussions with agency-level technology transfer office personnel, laboratory Office of Research and Technology Applications (ORTA) representatives, and other stakeholders point to areas that are likely to benefit from further analysis.

This chapter summarizes the study findings and proposes topics for future study.

A. Factors Affecting Technology Transfer that Leads to Commercialization

A fundamental point heard in discussions with ORTA staff was that the federal laboratories have diverse missions. These missions, which affect and are affected by the parent agency's mission, the laboratory operator and any affiliates, and the research portfolio of the laboratory, drive the laboratory's ability and interest in engaging in technology transfer that leads to commercialization. This study canvassed most of the R&D agencies, many of which are usually overlooked in studies of technology transfer, and it is clear the diversity of the subject laboratories cannot be overstated.

The federal laboratories' technology transfer activities do not operate in a vacuum. They are dependent on support and oversight from others, including laboratory directors, agency leadership, and Congress. According to interviewees, the level of support and oversight strongly affects how technology transfer occurs at a laboratory. Some ORTA personnel felt they had insufficient support from their laboratory director or agency leadership. Furthermore, not all agencies and laboratories have the same legal authorities to engage in technology transfer activities, leaving them with disparate capabilities.

ORTAs are the primary executors of technology transfer at the federal laboratories. Interviewees stated that the level of professionalism and the sharing of best practices across ORTAs have grown tremendously since their formal establishment through the

Stevenson-Wydler Act over 30 years ago. Nevertheless, ORTA representatives at some laboratories stated they are in need of additional areas of technology transfer expertise, especially business development. ORTA staff members also were not always aware of best practices employed in other federal laboratories, sometimes within their own agencies, primarily due to a lack of communication. This lack of communication also meant that there was variation in how ORTA personnel implemented agency policies. Furthermore, most laboratory ORTAs were not engaged with myriad other programs that exist in the federal government that support technology-based economic development.

While this study focused on the perspectives of members of ORTAs, we recognize that the scientists and engineers who perform research that leads to technology transfer at the federal laboratories are an integral component of technology transfer. According to the ORTA interviewees, although researchers are more aware than they had been in the past of the administrative aspects of technology transfer (such as when to file an invention disclosure or how to work with the ORTA to develop a patent application), researchers may still be lacking the ability, skills, and incentives to engage in partnerships with industry and pursue other commercially relevant research.

The federal laboratories represent about a third of the nation's investment in research and development. Groups designed to work with the laboratories and industry, however, stated that it is difficult for companies, especially small businesses, to know what technologies, resources, and capabilities the laboratories possess.

The process by which technologies are transferred can be challenging when the parties, in this case, the government and industry, have such different priorities, objectives, and approaches. Interviewees cited several agency policies that are viewed as being troublesome when developing agreements. Just as not all laboratories have similar legal authorities for technology transfer, the Government-Owned, Government-Operated (GOGO) laboratories do not have the ability to copyright software, although some have developed ways to circumvent the prohibition. The differences between government and industry result in a long timeline to reach most agreements, which industry states is a major barrier to working with the federal laboratories. To overcome the disparities that exist between government and industry, some laboratories use third-party intermediary organizations dedicated to promoting technology transfer and technology-based economic development.

Technology transfer that leads to commercialization requires dedicated and sustained resources, and it should not be seen as a self-sustaining activity. The federal laboratories have resources, technologies, and capabilities that are likely to be useful to industry, yet interviewees said they often do not have sufficient funding to allow researchers to engage in collaborative research activities. Furthermore, most of the laboratory research is in an early stage and requires further development before it can be transferred to industry. Interviewees indicated that only limited funds are available for technology maturation.

Many laboratories are engaging in interesting strategies to overcome some of the barriers listed above. Among these strategies are locating the ORTA within the laboratory where it has visibility to the organization; enhancing incentives for researchers to participate in technology transfer; using formal or informal partnership intermediaries to facilitate interactions between laboratories and industry; dedicating adequate resources to technology transfer and commercialization, including those for technology maturation; and highlighting and celebrating technology transfer within the laboratory.

B. Defining and Measuring Success

The management and measurement of technology transfer that leads to commercialization can be thought of as occurring at three different levels.

At the government-wide level, the measurement of technology transfer follows the guidance in the Federal Technology Transfer Act of 1986 and the Technology Transfer and Commercialization Act of 2000. Prior to 2007, the metrics were collected and reported by the Technology Administration (TA) office, but the responsibility was moved to NIST’s Technology Partnerships Office when the TA was disestablished by the America COMPETES Act of 2007. Many interviewees stated that the metrics in the annual interagency summary report to the President and Congress on technology transfer do not adequately reflect the diverse types of technology transfer that lead to commercialization at the laboratories. Metrics are provided at the agency level for a number of technology transfer activities and outputs, but cannot be used to make comparisons across agencies.

At the agency-wide level, metrics can be used to oversee and evaluate technology transfer at the laboratories, by either a technology transfer coordinator or agency leadership. Some agencies collect more metrics than are required for the annual report. Although agency ORTAs collect metrics from the laboratories for reporting purposes, it appears from interviews that the metrics are not used to manage technology transfer processes at the laboratories.

At the laboratory level, technology transfer success depends on how it fits into achieving laboratory missions. Most of the ORTA representatives interviewed for this study could not provide a definition of what success means for their laboratory and how specific components of technology transfer fit into achieving that mission. Without a definition for success, laboratories will not know which metrics are important to collect for achieving their mission.

Although additional metrics may be desired, especially for describing outputs and outcomes, the burden associated with collecting additional metrics should not be overlooked. Additional metrics can be expensive to collect and difficult to attribute to a single laboratory, and they may not reflect the success of a technology transfer program.

C. Opportunities for Further Study

Based on the findings from this study, we identified the following areas that would benefit from further study:

Study technology transfer at federal laboratories systematically and regularly to better understand technology transfer and commercialization activities across the laboratories. This study focused on a subset of the many laboratories that engage in technology transfer. Future studies could incorporate a larger group of laboratories to validate and refine the findings from this study. Furthermore, the current study asked laboratory ORTA personnel how technology transfer fits within achieving their laboratory's mission. It did not include an analysis of how others within the laboratory view technology transfer. A further study could evaluate the level of alignment between technology transfer and laboratory mission.

Study the perspectives of researchers, laboratory directors, and others within the laboratories. The results of this study were developed through discussions with only one set of stakeholders in the technology transfer process. The researchers at the laboratories also play an important role in technology transfer. A study as to whether they have the knowledge, resources, and incentives to engage in technology transfer would provide insight into how to better support technology transfer at the laboratories.

Another study of the barriers as perceived by industry could be done through a Request for Information (RFI), as the DOE did for its laboratories. Further delving into these barriers and how they can be overcome could be done through focus groups and conferences held with a variety of industry sectors and types.

Review of the available technology transfer legal authorities could reveal whether there are mechanisms that should be extended to all laboratories. Technology transfer at the laboratories occurs within a larger framework of policy and legislative guidance. Several interviewees stated that the legislative mechanisms might not be well-suited to today's realities for technology transfer. Furthermore, not all laboratories and agencies have the same legal authorities to engage in technology transfer. As part of this analysis, a survey of how these mechanisms are currently being used and whether new mechanisms should be developed could be included.

There were several provisions in legal agreements that industry has cited as being challenging when collaborating with the laboratories. A **content analysis of the legal agreement language** used by the laboratories, along with a study with laboratory and industry partners, could reveal how these provisions are dealt with in successful negotiations and whether there are core tenets that can be provided to both the laboratories and industry as guidelines when negotiating.

Another study would be to collect **technology transfer data at the laboratory level** for a more sophisticated portfolio analysis of technology transfer occurring at the federal intramural laboratories. This study would require agencies to provide the data they currently collect from the laboratories. Such a study could also include more advanced analyses on data available in the annual summary report to the President and Congress, such as the relationships between variables and more sophisticated normalizations based on detailed budget information.

An analysis of the existing technology-based federal, state and local economic development programs, where it would make sense for the laboratories to be engaged, could reveal areas for collaboration. There are several existing programs within the federal government designed to support technology-based economic development. Except for a few cases, however, laboratory ORTAs are not typically leveraging these programs.

D. Conclusion

The Department of Commerce requested this study to understand the current state of affairs in technology transfer and commercialization at federal laboratories. During this 6-month study, we completed an extensive review of the literature and interviewed staff at agency and federal laboratory technology transfer offices (referred to as ORTAs in this report). Based on the literature and interviews, we identified factors that facilitate technology transfer and commercialization. Areas for further study were identified to complete the landscape.

The federal laboratories are a source of our nation's current and future innovations. Technology transfer and commercialization activities at federal laboratories have evolved and grown over the last 30 years. Although this study revealed that barriers remain, there are also several strategies in place that other laboratories may find useful to replicate. For example, federal laboratories have increased their outreach to industry through partnership intermediary organizations, and many ORTAs have developed internal processes to streamline administrative functions to allow them to focus more fully on collaborating with industry. Defining successful technology transfer and representative metrics could be a first step to continuing to improve processes and outreach so that industry knows that the laboratories are "open for business." This landscape study pointed to many opportunities; further studies are likely to reveal additional insights of how to best support technology transfer and commercialization at the federal laboratories.

Appendix A: Descriptions of Agencies and Laboratories Interviewed

This appendix provides the mission statements of the agencies and laboratories interviewed as a part of this study, as well as the URLs of their respective Offices of Research and Technology Applications, when available.

Table A-1 shows characteristics of selected agencies and Table A-2 provides characteristics of selected laboratories from interviews conducted as a part of this study.

Table A-1. Characteristics of Selected Agencies

Agency	Year Established	Number of Laboratories	Intramural R&D ($M FY 2008)[a]	Year Technology Transfer Program Established
DHS	2002	5	$372	2008
DOC NOAA	1970	—	$447	—
DOD	1947	67	$16,185	1995
DOD ONR	1946	—	$5907[b]	—
DOE	1977	21[c]	$6,077	2005/2007[d]
DOI USGS	1879	35[e]	$490	—
EPA	1970	14	$395	—
HHS FDA	1927[f]	8	$108	1995[g]
HHS NIH	1930	21	$5,2483	1989[g]
NASA	1958	10	$2,280	1958
USDA	1862	100+	$1,448	—
VA	1930	89	$442	2000

[a] National Science Foundation/Division of Science Resources Statistics, preliminary federal obligations (including intramural, industry FFRDC, university FFRDC, and nonprofit FFRDC) for research and development, by agency and performer, FY 2008.

[b] Includes all Department of Navy.

[c] The DOE cites that they have 21 federal laboratories and technology centers. See http://www.energy.gov/organization/labs-techcenters.htm. They also cite that they have 17 federal laboratories. See http://science.energy.gov/laboratories/.

[d] Established following the Energy Policy Act of 2005; staffed in 2007.

[e] The USGS says it has 35 major laboratories and 100s of field offices.

[f] Formed in 1927 and transferred to Department of Health, Education and Welfare (now HHS) in 1953. See http://www.fda.gov/AboutFDA/WhatWeDo/History/Origin/ucm124403.htm.

[g] The FDA Technology Transfer Program manages the patenting and licensing portion of its activities through an interagency agreement with the NIH Office of Technology Transfer, because FDA does not have the staff to carry out the processing.

Table A-2. Characteristics of Selected Laboratories Interviewed by STPI

Agency	Laboratory	Year Established	BEA Region	Operator Type	Expenditures R&D budget ($M FY 2009)
DOC	NIST	1901	Mideast	GOGO	$452[a]
DOC	NOAA-ESRL	2005	Rocky Mountain	GOGO	—
DOC	NOAA-Hollings	2000	Southeast	GOGO	—
DOC	NOAA-CCEHBR	1941	Southeast	GOGO	—
DOD	AFRL	1997	Great Lakes	GOGO	—
DOD	ARDEC	1986	Mideast	GOGO	—
DOD	AMRMC	1994	Mideast	GOGO	—
DOD	NSWC-Crane	1941	Great Lakes	GOGO	—
DOE	LBNL	1931	Far West	GOCO	$582[b]
DOE	LLNL	1952	Far West	GOCO	$1,406[b]
DOE	LANL	1943	Southwest	GOCO	$2,292[b]
DOE	NREL	1991	Rocky Mountain	GOCO	$232[b]
DOE	ORNL	1943	Southeast	GOCO	$1,270[b]
DOE	PNNL	1965	Far West	GOCO	$1,153[b]
DOE	SNL	1949	Southwest	GOCO	$2,018[b]
DOE	SRNL	2004[c]	Southeast	GOCO	—
DOT	FAA-Hughes	1958	Mideast	GOGO	$293[a]
DOT	FRA	1966	Mideast	GOGO	$47[a]
DOT	RITA-Volpe	1970	New England	GOGO	—
HHS	NCI	1937	Mideast	GOGO	$781[d]
HHS	NHLBI	1948	Mideast	GOGO	$181[d]
HHS	NIAID	1948	Mideast	GOGO	$749[d]
HHS	NIDDK	1950	Mideast	GOGO	$176[d]
HHS	NINDS	1950	Mideast	GOGO	$154[d]
NASA	Goddard	1959	Mideast	GOGO	—
NASA	JPL[e]	1943	Far West	GOCO	$1,759[b]
USDA	BARC	1910	Mideast	GOGO	—

[a] National Science Foundation/Division of Science Resources Statistics, preliminary federal obligations (including intramural, industry FFRDC, university FFRDC, and nonprofit FFRDC) for research and development, by agency and performer, FY 2008 (except for DOE LLNL and LANL, which are from FY 2007 and FY 2006, respectively).

[b] National Science Foundation/Division of Science Resources Statistics, Total expenditures at federally funded research and development centers, by type of FFRDC, FY 2008 (except for DOE LLNL and LANL, which are from FY 2007 and FY 2006, respectively).

[c] The laboratory was established in 1951 to provide R&D support for the startup and operation of the Savannah River site.

[d] Intramural laboratory appropriations from HHS National Institutes of Health FY 2010 President's Budget: Mechanism Detail.

[e] JPL started as a military laboratory and then was transferred to NASA in 1958.

Department of Homeland Security

The Department of Homeland Security (DHS) was created in 2002 by the Homeland Security Act of 2002 (P.L. 107-296). According to the DHS website, the DHS's mission is "to secure the nation from the many threats we face."[1] DHS has five mission areas: Preventing Terrorism and Enhancing Security; Securing and Managing Our Borders; Enforcing and Administering Our Immigration Laws; Safeguarding and Securing Cyberspace; and Ensuring Resilience to Disasters. The Department of Homeland Security currently operates one centralized Office of Research and Technology Applications to manage technology transfer for all of its laboratories. The DHS Technology Transfer Program can be found online at http://www.dhs.gov/xabout/structure/gc_1264538499667.shtm.

Department of Commerce

The Department of Commerce (DOC), established in 1903,[2] "creates the conditions for economic growth and opportunity by promoting innovation, entrepreneurship, competitiveness, and stewardship informed by world-class scientific research and information."[3] The DOC has three main divisions, each with their own R&D activities: the National Institute of Standards and Technology (NIST); the National Oceanic and Atmospheric Administration (NOAA); and the National Telecommunications and Information Administration (NTIA). Technology transfer is decentralized across these three divisions.

DOC National Institute of Standards and Technology (Gaithersburg, MD)

NIST's mission is "to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life."[4] Technology transfer at NIST is performed by the NIST Technology Partnerships Office: http://www.nist.gov/tpo/.

DOC National Oceanic and Atmospheric Administration (Silver Spring, MD)

NOAA's mission is "to understand and predict changes in climate, weather, oceans and coasts; to share that knowledge and information with others; and to conserve and manage coastal and marine ecosystems and resources."[5] NOAA has a centralized Office of Research and Technology Applications: http://www.oar.noaa.gov/orta/.

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1 From http://www.dhs.gov/xabout/index.shtm (Last updated March 14, 2011)

2 From http://www.commerce.gov/about-department-commerce.

3 From http://www.osec.doc.gov/bmi/budget/DOC_Strategic_Plan_022311.pdf.

4 From http://www.nist.gov/public_affairs/general_information.cfm.

5 From http://www.ppi.noaa.gov/NGSP3/NGSP_ExecSumm.pdf.

DOC NOAA Center for Coastal Environmental Health and Biomolecular Research (Charleston, SC)

The Center for Coastal Environmental Health and Biomolecular Research's (CCEHBR) mission is to "conduct integrated environmental research and develop diagnostic tools to measure coastal ecosystem health."[6]

DOC NOAA Earth Systems Research Laboratory (Boulder, CO)

The Earth Systems Research Laboratory's (ESRL) mission is to "[t]o observe, understand, and predict the earth system through research that advances NOAA's environmental information and service from minutes to millennia on global-to-local scales."[7]

DOC NOAA Hollings Marine Laboratory (Charleston, SC)

Hollings Marine Laboratory's (HML) mission is "to provide science and biotechnology applications to sustain, protect, and restore coastal ecosystems, with emphasis on links between environmental condition and the health of marine organisms and humans."[8]

Department of Defense

The Department of Defense (DOD) was established in 1947 as the National Military Establishment, and reorganized as the modern Department of Defense in 1949. Its origins can be traced back to the Army, Navy and Marine Corps of 1775.[9] The mission of the DOD is "to provide the military forces needed to deter war and to protect the security of our country."[10] The agency has 67 research laboratories. Technology transfer at the DOD, although decentralized, is overseen by the Office of Technology Transition: http://www.acq.osd.mil/ott/.

DOD Air Force Research Laboratory (Wright Patterson Air Force Base, OH)

Air Force Research Laboratory's (AFRL) is dedicated to "leading the discovery, development and integration of affordable war-fighting technologies for America's aerospace forces."[11] AFRL's technology transfer is overseen by the Air Force Technology Transfer Program: http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=6026.

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6 From http://www.chbr.noaa.gov/about/mission.aspx.

7 From http://www.esrl.noaa.gov/.

8 From http://www.nist.gov/mml/hml/index.cfm.

9 From http://www.defense.gov/pubs/dod101/.

10 From http://www.defense.gov/about/.

11 From http://www.af.mil/information/factsheets/factsheet.asp?id=148.

DOD U.S. Army Armament Research, Development and Engineering Center (Picatinny, NJ)

U.S. Army Armament Research, Development and Engineering Center (ARDEC)'s mission is to: "to develop and maintain a world-class workforce to execute and manage integrated life cycle engineering processes required for the research, development, production, field support and demilitarization of munitions, weapons, fire control and associated items."[12] ARDEC's Technology Transfer Program can be found at: http://www.pica.army.mil/TechTran/.

DOD U.S. Army Medical Research and Materiel Command (Fort Detrick, MD)

The U.S. Army Medical Research and Materiel Command's (AMRMC) mission is to "provide medical material to sustain the health, well being and military readiness of U.S service men and women."[13] AMRMC's Office of Research and Technology Applications coordinates licensing for all subordinate laboratories: https://technologytransfer.detrick.army.mil/.

DOD Office of Naval Research (Arlington, VA)

The Office of Naval Research's mission is "to plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power, and the preservation of national security."[14] Technology transfer within ONR's laboratories is coordinated by the Navy Technology Transfer Program: http://www.onr.navy.mil/en/Science-Technology/Directorates/Transition/Technology-Transfer-T2.aspx.

DOD ONR Naval Surface Warfare Center Crane Division (Crane, IN)

Naval Surface Warfare Center (NSWC) Crane Division's mission is to "provide acquisition engineering, in-service engineering and technical support for sensors, electronics, electronic warfare, and special warfare weapons; to apply component and system level product and industrial engineering to surface sensors, strategic systems, special warfare devices and electronic warfare/information operations systems; and to execute other responsibilities as assigned by the Commander, Naval Surface Warfare Center."[15] NSWC's technology transfer program includes both partnering and a Technology Engagement Office: http://www.navsea.navy.mil/nswc/crane/working/Pages/Technology%20Transfer.aspx?PageView=Shared.

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[12] From http://www.pica.army.mil/picatinnypublic/organizations/ardec/index.asp.

[13] From http://www.flcmidatlantic.org/power_point/2007/2007_Meeting/Mele.ppt.

[14] From http://www.onr.navy.mil/About-ONR/science-technology-strategic-plan.aspx.

[15] From http://www.navsea.navy.mil/nswc/crane/aboutus/default.aspx.

Department of Energy

The Department of Energy (DOE) was officially established in 1977, in response to the energy crisis of the 1970s, although its precursors can be traced back to the Manhattan project in 1942 and the Atomic Energy Commission in 1946.[16] DOE's mission is to "ensure America's security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions."[17] The agency has 21[18] research laboratories and technology centers.[19] Technology transfer at the DOE is decentralized, but is coordinated through their Technology Transfer Program: http://techtransfer.energy.gov/.

DOE Lawrence Berkeley National Laboratory (Berkeley, CA)

The Lawrence Berkeley National Laboratory (LBNL) mission is "bringing science solutions to the world." LBNL is managed by the University of California. Technology transfer is performed by LBNL's Technology Transfer and Intellectual Property Management Department: http://www.lbl.gov/Tech-Transfer/.

DOE Lawrence Livermore National Laboratory (Livermore, CA)

The Lawrence Livermore National Laboratory (LLNL) mission is to "to ensure the safety and security of the nation through applied science and technology in three key areas: nuclear security, international and domestic security, and environmental security."[20] LLNL is operated by Lawrence Livermore National Security, LLC, for the DOE's National Nuclear Security Administration (NNSA). Technology transfer at LLNL is handled by the Industrial Partnerships Office: https://ipo.llnl.gov/.

DOE Los Alamos National Laboratory (Los Alamos, NM)

Los Alamos National Laboratory's (LANL) mission is "to develop and apply science and technology to: ensure the safety, security, and reliability of the U.S. nuclear deterrent, reduce global threats, and solve other emerging national security challenges."[21] LANL is operated by Los Alamos National Security, LLC for the DOE's NNSA. LANL's Technology Transfer Division operates the technology transfer activities for the laboratory: http://www.lanl.gov/partnerships/.

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16 From http://www.energy.gov/about/origins.htm.

17 From http://www.energy.gov/about/index.htm.

18 DOE cites that they have 21 federal laboratories and technology centers. See http://www.energy.gov/organization/labs-techcenters.htm. They also cite that they have 17 federal laboratories. See http://science.energy.gov/laboratories.

19 From http://www.energy.gov/organization/labs-techcenters.htm.

20 From https://www.llnl.gov/about/whatwedo.html.

21 From http://www.lanl.gov/natlsecurity/.

DOE National Renewable Energy Laboratory (Golden, CO)

The National Renewable Energy Laboratory (NREL) "develops renewable energy and energy efficiency technologies and practices, advances related science and engineering, and transfers knowledge and innovations to address the nation's energy and environmental goals."[22] NREL is operated by Alliance for Sustainable Energy, LLC for the DOE's Office of Energy Efficiency and Renewable Energy. Technology transfer is handled by NREL's Commercialization and Technology Transfer Office: http://www.nrel.gov/technologytransfer/.

DOE Oak Ridge National Laboratory (Oak Ridge, TN)

Oak Ridge National Laboratory (ORNL) "pioneers the development of new energy sources, technologies, and materials and the advancement of knowledge in the biological, chemical, computational, engineering, environmental, physical, and social sciences."[23] ORNL is managed by UT-Battelle for the DOE's Office of Science. Technology transfer at ORNL is handled by the Partnerships Division: http://www.ornl.gov/adm/partnerships/.

DOE Pacific Northwest National Laboratory (Richland, WA)

The Pacific Northwest National Laboratory's (PNNL) mission is "to deliver leadership and advancements in science, energy, national security and the environment for the benefit of the U.S. Department of Energy and the nation."[24] PNNL is operated by Battelle for DOE's Office of Science. Technology transfer at PNNL is handled by their Technology Transfer Program: http://www.pnl.gov/business/tech_transfer.aspx.

DOE Sandia National Laboratories (Albuquerque, NM)

Sandia National Laboratories (SNL) focuses on five mission areas: Nuclear Weapons, Energy and Infrastructure Assurance, Nonproliferation, Defense Systems and Assessments, and Homeland Security & Defense.[25] Sandia Corporation, a Lockheed Martin company, manages SNL for the DOE's National Nuclear Security Administration (NNSA). SNL's Partnerships Office handles technology transfer: http://www.sandia.gov/bus-ops/partnerships/index.html.

DOE Savannah River National Laboratory (Aiken, SC)

Savannah River National Laboratory (SRNL) "applies its unique expertise and applied technology capabilities to reduce technical uncertainties in order to assist sites

[22] From http://www.nrel.gov/overview/.

[23] From http://www.ornl.gov/ornlhome/about.shtml.

[24] From http://www.PNNL.gov/about/mission.asp.

[25] From http://www.sandia.gov/mission/.

across the DOE Complex in meeting cleanup requirements."[26] SRNL is managed and operated for the DOE's Office of Environmental Management by Savannah River Nuclear Solutions, LLC. Technology transfer at SRNL is performed by the Technology Transfer office: http://srnl.doe.gov/tech_transfer/tech_transfer.htm.

Department of Interior

The Department of the Interior (DOI) was established in 1849.[27] The mission of DOI is to protect "America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future."[28] DOI consists of eight bureaus: The U.S. Geological Survey; Bureau of Reclamation; Bureau of Land Management; Fish and Wildlife Service; Minerals Management Service; the National Park Service; Bureau of Indian Affairs; and the Office of Surface Mining. The majority of DOI's research is performed by USGS, created in 1879.[29]

DOI U.S. Geological Survey (Reston, VA)

U.S. Geological Survey (USGS) is "a science organization that provides impartial information on the health of our ecosystems and environment, the natural hazards that threaten us, the natural resources we rely on, the impacts of climate and land-use change, and the core science systems that help us provide timely, relevant, and useable information."[30] USGS has 35 major laboratories and several hundred field offices located around the country. Technology transfer is handled centrally by the USGS ORTA: http://www.usgs.gov/tech-transfer/index.html.

Department of Transportation

The Department of Transportation (DOT) was established by an act of Congress in 1966.[31] DOT's mission is to "serve the United States by ensuring a fast, safe, efficient, accessible and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future."[32] DOT conducts research to improve safety and mobility at its seven major research laboratories. DOT recently instituted a technology transfer coordinator to coordinate technology transfer at their laboratories.

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[26] From http://srnl.doe.gov/facts/overview09.pdf.

[27] From http://www.doi.gov/whoweare/history.cfm.

[28] From http://www.doi.gov/whoweare/Mission-Statement.cfm.

[29] From http://www.usgs.gov/aboutusgs/who_we_are/history.asp.

[30] From http://www.usgs.gov/aboutusgs/.

[31] From http://dotlibrary.dot.gov/Historian/history.htm. RITA stands for Research and Innovative Technology Administration (RITA) at the Department of Transportation.

[32] From http://www.dot.gov/about.html.

DOT RITA John A. Volpe National Transportation Systems Center (Cambridge, MA)

The John A. Volpe National Transportation Systems Center's (Volpe Center) mission is "to improve the nation's transportation systems."[33] Volpe's technology transfer is accomplished through its technology transfer program, which also operates the SBIR program: http://www.volpe.dot.gov/ourwork/techtrns.html.

DOT The FAA William J. Hughes Technical Center (Atlantic City, NJ)

The FAA William J. Hughes Technical Center's (FAA-Hughes) mission is "To provide integrated engineering and research services for the development and support of a safe, secure and efficient global aviation system."[34] The Technology Transfer Program Office handles all technology transfer from FAA-Hughes: http://www.tc.faa.gov/technologytransfer/sbir/.

DOT Federal Railroad Administration (Washington, DC)

The purpose of the Federal Railroad Administration's (FRA) mission is to "The purpose of FRA is to: promulgate and enforce rail safety regulations; administer railroad assistance programs; conduct research and development in support of improved railroad safety and national rail transportation policy; provide for the rehabilitation of Northeast Corridor rail passenger service; and consolidate government support of rail transportation activities."[35]

Environmental Protection Agency

The Environmental Protection Agency (EPA) was established by the National Environmental Policy Act of 1970.[36] EPA's mission is "to protect human health and to safeguard the natural environment."[37] The agency has 14 research laboratories and centers.[38] Technology transfer at EPA is overseen by the EPA's Technology Transfer staff: http://www.epa.gov/osp/ftta.htm.

Department of Health and Human Services

The Department of Health and Human Services (HHS) was established by President Eisenhower in 1953 as the Department of Health, Education and Welfare, and officially became the HHS in 1980.[39] "The Department of Health and Human Services is the

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33 From http://www.volpe.dot.gov/about/mission.html.

34 From http://www.tc.faa.gov/TC_mission.html.

35 From http://www.fra.dot.gov/Pages/2.shtml

36 From http://www.epa.gov/history/topics/epa/15c.htm.

37 From http://www.epa.gov/history/.

38 From http://www.epa.gov/aboutepa/index.html#labs (excluding regional laboratories).

39 From http://www.hhs.gov/about/hhshist.html.

United States government's principal agency for protecting the health of all Americans and providing essential human services, especially for those who are least able to help themselves."[40] The department's research is accomplished by three main branches: the National Institutes of Health (NIH), the Food and Drug Administration (FDA), and the Centers for Disease Control.

HHS National Institutes of Health (Bethesda, MD)

The National Institutes of Health's mission is "to seek fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to enhance health, lengthen life, and reduce the burdens of illness and disability."[41] NIH consists of 27 Institutes and Centers.[42] The NIH's Office of Technology Transfer manages patenting and licensing for the 27 NIH Institutes and Centers, assists the FDA's Technology Transfer Program, and helps to develop HHS-wide technology transfer policies: http://www.ott.nih.gov/.

NIH Institutes and Centers manage invention reporting, Material Transfer Agreements, CRADAs and other types of collaborative research agreements.

HHS NIH National Cancer Institute (Bethesda, MD)

The National Cancer Institute (NCI) is "the Federal Government's principal agency for cancer research and training"[43] and its mandate includes a "requirement to assess the incorporation of state-of-the-art cancer treatments into clinical practice."[44] CRADAs and other Institute technology transfer activities are performed by the NCI's Technology Transfer Center: http://ttc.nci.nih.gov/.

HHS NIH National Heart, Lung and Blood Institute (Bethesda, MD)

The National Heart, Lung, and Blood Institute (NHLBI) "provides global leadership for a research, training, and education program to promote the prevention and treatment of heart, lung, and blood diseases and enhance the health of all individuals so that they can live longer and more fulfilling lives."[45] NHLBI's Office of Technology Transfer and Development handles Institute technology transfer: http://www.nhlbi.nih.gov/resources/tt/index.htm.

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[40] From http://www.hhs.gov/about/whatwedo.html.

[41] From http://www.nih.gov/about/mission.htm

[42] From http://www.nih.gov/about/almanac/organization/index.htm

[43] From http://www.cancer.gov/aboutnci/overview/mission

[44] From http://www.cancer.gov/aboutnci/overview/mission.

[45] From http://www.nhlbi.nih.gov/about/org/mission.htm.

HHS NIH National Institute of Allergy and Infectious Diseases (Bethesda, MD)

The National Institute of Allergy and Infectious Diseases (NIAID) "conducts and supports basic and applied research to better understand, treat, and ultimately prevent infectious, immunologic, and allergic diseases."[46] Technology transfer at NIAID is handled by their Office of Technology Development: http://www.niaid.nih.gov/labsandresources/techdev/pages/default.aspx.

HHS NIH National Institute of Diabetes and Digestive and Kidney Diseases (Bethesda, MD)

The National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) "conducts and supports research on many of the most serious diseases affecting public health. The Institute supports much of the clinical research on the diseases of internal medicine and related subspecialty fields, as well as many basic science disciplines."[47] NIDDK's Office of Technology Transfer and Development handles technology transfer for the Institute: http://www2.niddk.nih.gov/TechDev/Main-HomePage/.

HHS NIH National Institute of Neurological Disorders and Stroke (Bethesda, MD)

The mission of the National Institute of Neurological Disorders and Stroke (NINDS) is "to reduce the burden of neurological disease - a burden borne by every age group, by every segment of society, by people all over the world."[48] NINDS has a technology transfer offices, but it uses the services of the NCI Technology Transfer Center for technology transfer and development activities: http://tto.ninds.nih.gov/.

HHS U.S. Food and Drug Administration (Rockville, MD)

The Food and Drug Administration (FDA) "is responsible for: protecting the public health by assuring that foods are safe, wholesome, sanitary and properly labeled; human and veterinary drugs, and vaccines and other biological products and medical devices intended for human use are safe and effective; protecting the public from electronic product radiation; assuring cosmetics and dietary supplements are safe and properly labeled; regulating tobacco products; advancing the public health by helping to speed product innovations; and helping the public get the accurate science-based information they need to use medicines, devices, and foods to improve their health."[49] FDA's CRADAs, MTAs, and other similar technology transfer activities are performed by FDA's Technology Transfer Program:

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[46] From http://www.nih.gov/about/almanac/organization/NIAID.htm#mission.

[47] From http://www.nih.gov/about/almanac/organization/NIDDK.htm.

[48] From http://www.ninds.nih.gov/about_ninds/mission.htm.

[49] From http://www.fda.gov/AboutFDA/Transparency/Basics/ucm194877.htm.

http://www.fda.gov/AboutFDA/business/ucm119486.htm. In conjunction with the FDA's Technology Transfer Program, patenting and licensing of FDA's technologies is coordinated with assistance from the NIH's Office of Technology Transfer.

National Aeronautics and Space Administration

The National Aeronautics and Space Administration (NASA) was established in 1958, partially in response to the launch of the Soviet Sputnik satellite.[50] NASA's vision is "to reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind."[51] NASA has 10 field centers; technology transfer is overseen by NASA's Office of the Chief Technologist: http://www.nasa.gov/offices/oct/partnership/tech_transfer.html.

NASA Goddard Space Flight Center (Greenbelt, MD)

The Goddard Space Flight Center (GSFC) "manages many of NASA's Earth observation, astronomy, and space physics missions."[52] GSFC includes several facilities other than the main campus located in Greenbelt, MD. Technology transfer at GSFC is handled by its Innovative Partnerships Program: http://ipp.gsfc.nasa.gov/.

NASA Jet Propulsion Laboratory (Pasadena, CA)

The Jet Propulsion Laboratory (JPL) directs unmanned planetary missions for the United States. JPL helps the United States solve technological problems and performs research, development and spaceflight activities for NASA and other agencies."[53] The California Institute for Technology (Caltech) manages JPL for NASA. Patenting and licensing of JPL's technologies is performed by Caltech's Office of Technology Transfer, but research partnerships and other technology transfer is done by JPL's Innovative Partnerships Program: http://technology.jpl.nasa.gov/opportunities/industry/innovativepartnershipprogram/.

U.S. Department of Agriculture

The Department of Agriculture (USDA) was established in 1862 with the signing of the Agricultural Act.[54] The mission of the Agriculture Research Service is "to develop new knowledge and technology needed to solve technical agricultural problems of broad scope and high national priority in order to ensure adequate production of high-quality food and agricultural products to meet the nutritional needs of the American consumer, to sustain a

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50 From http://history.nasa.gov/brief.html.

51 From http://www.nasa.gov/about/highlights/what_does_nasa_do.html.

52 From http://www.nasa.gov/centers/goddard/about/facilities.html.

53 From http://www.federallabs.org/labs/profile/?id=1434.

54 From http://riley.nal.usda.gov/nal_display/index.php?info_center=8&tax_level=2&tax_subject=3&topic_id=1033.

viable food and agricultural economy, and to maintain a quality environment and natural resource base."[55] The Agricultural Research Service (ARS) is the major in-house research arm of USDA[56] and administers the patents and licenses for USDA. ARS has over 100 research laboratories.[57] Technology transfer at USDA is coordinated by ARS's Office of Technology Transfer: http://www.ars.usda.gov/business/docs.htm?docid=763.

USDA Agricultural Research Service (ARS) Beltsville Agricultural Research Center

Beltsville Agricultural Research Center (BARC) addresses ARS-wide goals through several different programs.[58] Technology Transfer for BARC is handled through ARS's Office of Technology Transfer.

Veterans Affairs

Veterans Affairs was established in 1930 upon the consolidation of all government activities affecting war veterans.[59] Its mission was "to fulfill Lincoln's promise "To care for him who shall have borne the battle, and for his widow, and his orphan" by serving and honoring the men and women who are America's veterans."[60] The Department of Veterans Affairs (VA) was established as a Cabinet-level position in 1989. The agency's intramural research is performed by the Veterans Health Administration Office of Research and Development at close to 90 medical centers around the country. Technology transfer at the VA is overseen by the VA Technology Transfer Program: http://www.research.va.gov/programs/tech_transfer/default.cfm.

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55 From http://www.ars.usda.gov/pandp/locations/locations.htm?modecode=01-01-00-00.

56 AAAS lists 4 research "agencies" within USDA at http://www.aaas.org/spp/rd/rdreport2011/11pch10.pdf.

57 From http://www.ars.usda.gov/is/np/ha/hanlabs.htm.

58 From http://www.ars.usda.gov/AboutUs/AboutUs.htm?modecode=12-00-00-00

59 From http://www.va.gov/about_va/vahistory.asp.

60 From http://www4.va.gov/about_va/mission.asp.

Appendix B: Legislative Summary and Matrix

This appendix provides chronological descriptions of selected technology transfer legislation, followed by a matrix (Table B-1) that shows the applicability of each statute to the various federal laboratories.

Chronological Summary of Selected Technology Transfer Legislation[1]

Executive Order 10096 (1950): Providing for a Uniform Patent Policy for the Government with Respect to Inventions Made by Government Employees and for the Administration of Such Policy

- Gave the government the entire right, title and interest in and to all inventions made by any government employee (1) during working hours, or (2) with a contribution by the government of facilities, equipment, materials, funds, or information, or of time or services of other government employees on official duty, or (3) which bear a direct relation to or are made in consequence of the official duties of the inventor.

National Aeronautics and Space Act of 1958 (P.L. 85-568)

- Authorized the NASA Administrator to enter into and perform such contracts, leases, cooperative agreements, or other transactions as may be necessary in the conduct of its work and on such terms as it may deem appropriate, with any agency or instrumentality of the United States, or with any State, Territory, or possession, or with any political subdivision thereof, or with any person, firm, association, corporation, or educational institution;
- Permitted the NASA Administrator to engage in international cooperative programs pursuant to NASA's mission.

Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480; 15 U.S.C. §§3701–3714)

- Focused on dissemination of information;
- Required federal laboratories to take an active role in technical cooperation;

[1] Adapted from RAND (2003) and FLC (2009).

- Established Offices of Research and Technology Application at major federal laboratories (those with R&D budgets of $20 million or more);
- Set maximum royalty award for researchers at $100,000.

Bayh-Dole Act of 1980 (P.L. 96-517)

- Allowed Government-Owned, Government-Operated (GOGO) laboratories to grant exclusive licenses to patents.

Small Business Innovation Development Act of 1982 (P.L. 97-219)

- Required agencies to provide special funds for small-business R&D connected to the agencies' missions;
- Established the Small Business Innovation Research Program (SBIR).

Trademark Clarification Act of 1984 (P.L. 98-620)

- Permitted decisions to be made at the laboratory level in Government-Owned, Contractor-Operated (GOCO) laboratories as to awarding licenses for patents;
- Permitted contractors to receive patent royalties for use in R&D or awards, or for education;
- Permitted private companies, regardless of size, to obtain exclusive licenses;
- Permitted laboratories run by universities and nonprofit institutions to retain title to inventions, within limitations.

Federal Technology Transfer Act of 1986 (P.L. 99-502)

- Made technology transfer a responsibility of all federal laboratory scientists and engineers;
- Mandated that technology transfer responsibility be considered in employee performance evaluations;
- Changed requirement for ORTAs to be for laboratories with 200 or more full-time equivalent scientific, engineering, and related technical positions;
- Established a principle of royalty sharing for federal inventors (15 percent minimum) and set up a reward system for other innovators;
- Legislated a charter for the Federal Laboratory Consortium for Technology Transfer and provided a funding mechanism for that organization to carry out its work;

- Empowered each agency to give the director of GOCO laboratories authority to enter into cooperative R&D agreements and negotiate licensing agreements with streamlined headquarters review;
- Allowed laboratories to make advance agreements with large and small companies on title and license to inventions resulting from Cooperative R&D Agreements (CRADAs) with government laboratories;
- Allowed directors of GOGO laboratories to negotiate licensing agreements for inventions made at their laboratories;
- Provided for exchanging GOGO laboratory personnel, services, and equipment with their research partners;
- Made it possible to grant and waive rights to GOGO laboratory inventions and intellectual property;
- Allowed current and former federal employees to participate in commercial development, to the extent that there is no conflict of interest.

Executive Orders 12591 and 12618 (1987): Facilitating Access to Science and Technology

- Encouraged GOGO laboratories to enter into cooperative agreements;
- Required, to the extent permitted by law, laboratories to grant contractors title to patents developed in whole or in part with federal funds, so long as government reserved a royalty-free license to practice.

Omnibus Trade and Competitiveness Act of 1988 (P.L. 100-148)

- Placed emphasis on the need for public/private cooperation in assuring full use of results and resources;
- Changed the name of the National Bureau of Standards to the National Institute of Standards and Technology and broadened its technology transfer role;
- Extended royalty payment requirements to nongovernment employees of federal laboratories.

National Institute of Standards and Technology Authorization Act for FY 1989 (P.L. 100-519)

- Established a Technology Administration within the Department of Commerce;
- Permitted contractual consideration for rights to intellectual property, other than patents, in cooperative research and development agreements;
- Clarified the rights of NIST guest worker inventors regarding royalties.

Water Resources Development Act of 1988 (P.L. 100-676)

- Authorized Army Corps of Engineers laboratories and research centers to enter into cooperative research and development agreements;
- Allowed the Corps to fund up to 50 percent of the cost of the cooperative project.

National Competitiveness Technology Transfer Act of 1989 (P.L. 101-189)

- Granted GOCO federal laboratories the opportunity to enter into CRADAs and other activities with universities and private industry, under essentially the same terms as stated under the Federal Technology Transfer Act of 1986;
- Allowed information and innovations, brought into and created through cooperative agreements, to be protected from disclosure;
- Provided a technology transfer mission for the nuclear weapons laboratories.

Defense Authorization Act for FY 1991 (P.L. 101-510)

- Established model programs for national defense laboratories to demonstrate successful relationships among federal government, state and local governments, and small businesses;
- Allowed a federal laboratory to enter into a contract or memorandum of understanding with a partnership intermediary to perform services related to cooperative or joint activities with small businesses;
- Provided for the development and implementation of a National Defense Manufacturing Technology Plan.

Intermodal Surface Transportation Efficiency Act of 1991 (P.L. 102-240)

- Authorized the Department of Transportation to provide not more than 50 percent of the cost of CRADAs for highway research and development.
- Encouraged innovative solutions to highway problems and stimulated the marketing of new technologies on a cost-shared basis of more than 50 percent if there is substantial public interest or benefit.

American Technology Preeminence Act of 1991 (P.L. 102-245)

- Extended Federal Laboratory Consortium for Technology Transfer (FLC) mandate, removed FLC responsibility for conducting a grant program, and required the inclusion of the results of an independent annual audit in the FLC summary report to Congress and the President;
- Included intellectual property as potential contributions under CRADAs;

- Required the Secretary of Commerce to report on the advisability of authoring a new form of CRADA that permits federal contributions of funds;
- Allowed laboratory directors to give excess equipment to educational institutions and nonprofit organizations as a gift.

Small Business Technology Transfer (STTR) Act of 1992 (P.L. 102-564)

- Established a three-year pilot program—Small Business Technology Transfer (STTR)—at the Department of Defense (DOD), Department of Energy (DOE), Department of Health and Human Services (HHS), the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF);
- Directed the Small Business Administration (SBA) to oversee and coordinate the implementation of the STTR Program;
- Designed the STTR to be similar to the Small Business Innovation Research (SBIR) program. Some laboratories can apply directly for STTRs
- Required each of the five agencies listed above to fund cooperative R&D projects involving a small company and a researcher at a university, federally funded research and development center, or nonprofit research center.

National Defense Authorization Act for Fiscal Year 1993 (P.L. 102-484)

- Required the Department of Defense to establish an DOD Office of Technology Transition;
- Extended the potential for CRADAs to some DOD-funded Federally Funded Research and Development Centers (FFRDCs) not owned by the government;
- Extended the streamlining of small-business technology transfer procedures for nonfederal laboratory contractors;
- Directed the DOE to issue guidelines to facilitate technology transfer to small businesses.

National Defense Authorization Act for Fiscal Year 1994 (P.L. 103-160)

- Broadened the definition of a laboratory to include the weapons production facilities of the DOE.

National Technology Transfer and Advancement Act of 1995 (P.L. 104-113)

- Guaranteed a Cooperative Research and Development Agreement (CRADA) industrial partner the option to choose an non exclusive or exclusive license to the resulting invention in a field-of-use;

- Required CRADA partners to grant the government a royalty free license to use the invention for their purposes but it must not publicly disclose trade secrets of commercial or financial information;
- Stated that the government will not use march-in rights except under exceptional circumstances;
- Partners retain title to inventions made solely by their employees in exchange for royalty free license for government, but this license is not mandatory;
- Explained that agencies may use royalties to hire temporary personnel to assist in CRADA or related projects;
- Restated right for current and former government employees to assist in commercialization of inventions;
- Restated and clarified that a federal employee inventor can obtain or retain title to his/her invention if government does not choose to patent or commercialize it;
- Required federal laboratories to give first $2,000 of royalty income to the inventors and increases an inventor's maximum royalty award to $150,000 per year;
- Allowed laboratories to use royalties for related research in the laboratory.

Technology Transfer Commercialization Act of 2000 (P.L. 106-404)

- Improved the ability of federal agencies to license federally owned inventions by reforming technology training authorities under the Bayh-Dole Act;
- Permitted laboratories to bring already existing government inventions into a CRADA.

Ronald W. Reagan National Defense Authorization Act for FY 2005 (P.L. 108-375)

- Permitted Defense Secretary to license trademarks and retain and expend fees received from licensing;
- Required fees to be used to pay trademark and licensing costs and for morale, welfare and recreation activities.

Energy Policy Act of 2005 (P.L. 109-58)

- Required the Department of Energy to establish a technology transfer coordinator position as the principal advisor to the secretary on all matters related to technology transfer and commercialization;

- Founded a technology transfer working group to coordinate technology transfer activities at the DOE laboratories (with oversight by the technology transfer coordinator);
- Endowed an energy technology commercialization fund to provide matching funds with private partners to promote energy technologies for commercial purposes.

NASA Authorization Act of 2005 (P.L. 109-155)

- Called for NASA to develop a commercialization plan for technology transfer and for translating space research to advance the United States economy.

America COMPETES Act 2007 (P.L. 110-69)

- Eliminated the Department of Commerce Office of Technology Administration, and the associated Under Secretary, which had the principal reporting and analytical responsibilities for technology transfer activities government-wide (these duties were reassigned within Commerce);
- Initiated a President’s Council on Innovation and Competitiveness to develop a comprehensive agenda to promote the economic competitiveness of the United States.

Table B-1. Matrix of Selected Technology Transfer Legislation Affecting Federal Laboratories

<table>
<tr><th rowspan="2">Time Period</th><th rowspan="2">Legislation</th><th colspan="2">All Federal Laboratories</th></tr>
<tr><th>GOGO</th><th>GOCO</th></tr>
<tr><td>Pre-1980</td><td>Executive Order 10096 (1950)</td><td>All rights to inventions made by government employees within scope of employment are assigned to government.</td><td></td></tr>
<tr><td rowspan="7">1980–1989</td><td>Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480)</td><td colspan="2">Established Offices of Research and Technology Application (ORTAs) at major federal laboratories. Set maximum annual royalty award for researchers at $100,000.</td></tr>
<tr><td>Bayh-Dole Act of 1980 (P.L. 96-517)</td><td>Allowed GOGO laboratories to grant exclusive licenses to patents. Provided invention descriptions with early IP rights protection from public dissemination and FOIA disclosure.</td><td></td></tr>
<tr><td>Small Business Innovation Development Act of 1982 (P.L. 97-219)</td><td colspan="2">Established the Small Business Innovation Research Program (SBIR). Required agencies to provide special funds for small-business R&D connected to the agencies’ missions.</td></tr>
<tr><td rowspan="2">Trademark Clarification Act of 1984 (P.L. 98-620)</td><td colspan="2">Permitted private companies, regardless of size, to obtain exclusive licenses.</td></tr>
<tr><td></td><td>Permitted decisions to be made at the laboratory level in GOCO laboratories as to awarding licenses for patents; laboratories run by universities and nonprofits to retain title to inventions, within limitations; and contractors to receive patent royalties for use in R&D or awards, or for education.</td></tr>
<tr><td rowspan="2">Federal Technology Transfer Act of 1986 (P.L. 99-502)</td><td colspan="2">Made technology transfer a responsibility of all federal laboratory S&Es and mandated it be considered in employee evaluations. Established a principle of royalty sharing for federal inventors (15 percent minimum) and set up a reward system for other innovators. Legislated a charter for the FLC and provided a funding mechanism.</td></tr>
<tr><td>Allowed laboratories to make advance agreements with large and small companies on title and license to inventions resulting from CRADAs with government laboratories. Allowed current and former federal employees to participate in commercial development, to the extent that there is no conflict of interest.</td><td>Empowered each agency to give the director of GOCO laboratories authority to enter into CRADAs and negotiate licensing agreements with streamlined HQ review.</td></tr>
</table>

Time Period	Legislation	All Federal Laboratories	
		GOGO	GOCO
1980–1989	*Executive Orders 12591 and 12618 (1987)*	Head of each agency shall encourage TT and facilitate collaboration among Federal laboratories, State and local governments, universities, and the private sector, particularly small business, in order to assist in the transfer of technology to the marketplace.	
		Encouraged GOGO laboratories to enter into cooperative agreements and grant licenses	Required, to the extent permitted by law, laboratories to grant contractors title to patents developed in whole or in part with federal funds, so long as government reserved a royalty-free license to practice.
	Omnibus Trade and Competitiveness Act of 1988 (P.L. 100-148)	Extended royalty payment requirements to nongovernment employees of federal laboratories.	
	National Institute of Standards and Technology Authorization Act for FY 1989 (P.L. 100-519)	Permitted contractual consideration for rights to IP, other than patents in CRADAs. Allowed software development contributors to be eligible for awards. Clarified the rights of guest worker inventors regarding royalties.	
	National Competitiveness Technology Transfer Act of 1989 (P.L. 101-189)		Granted GOCO laboratories the authority to enter into CRADAs under same terms as FTTA. Allowed info and innovations brought into and created through cooperative agreements to be protected from disclosure.
1990–1999	*National Department of Defense Authorization Act for FY 1991 (P.L. 101-510)*	Allowed a federal laboratory to enter into a contract or MOU with a partnership intermediary to perform services related to cooperative or join activities with small businesses.	
	American Technology Preeminence Act of 1991 (P.L. 102-245)	Extended FLC mandate, removed responsibility for conducting a grant program, and required the inclusion of the results of an independent annual audit in FLC summary report to Congress and the President. Included IP as a potential contribution under a CRADA.	
	Small Business Technology Transfer (STTR) Act of 1992 (P.L. 102-564)	Established a three-year pilot program—Small Business Technology Transfer (STTR)—at the DOD, DOE, HHS, NASA, and NSF. Directed the Small Business Administration (SBA) to oversee and coordinate the implementation of the STTR Program. Designed the STTR to be similar to the Small Business Innovation Research (SBIR) program. Required each of the five agencies listed above to fund cooperative R&D projects involving a small company and a researcher at a university, federally funded research and development center, or nonprofit research center.	
	National Technology Transfer and Advancement Act of 1995 (P.L. 104-113)	Guaranteed CRADA partners the option to choose a nonexclusive or exclusive license in a field of use. Granted government a royalty-free use license but government must not disclose trade secrets. Gave first $2,000 royalty income to inventor(s) and increased cap to $150,000.	
2000–2009	*Technology Transfer Commercialization Act of 2000 (P.L. 106-404)*	Permitted laboratories to bring already existing government inventions into a CRADA. Reformed technology training authorities under the Bayh-Dole Act.	

Appendix C: Descriptions of Selected Mechanisms and Matrix by Agency

This appendix defines some of the common technology transfer mechanisms and identifies the federal agencies that use them. Mechanisms are categorized by direct transfer of property, partnership agreements, resource use agreements, educational agreements, personnel exchange agreements and agreements with partnership intermediaries. At the end of the appendix, Table C-1 provides the authorities for each agency by mechanism.

Direct Transfer of Property

Material Transfer Agreements

Material Transfer Agreements (MTAs) govern the conveyance of tangible research materials from a federal laboratory to an outside entity. MTAs may be used for biological materials, such as reagents, cell lines, plasmids, and vectors; chemical compounds; and some types of software. Transferred material is used for basic research, testing, or feasibility studies, depending on the substance. The main purpose of the MTA is not just to protect federal IP but also to assure essential conditions on use (e.g., safety constraints on biological materials transferred by HHS laboratories). MTAs are used by all HHS federal laboratories (NIH, FDA, CDC), Department of Commerce (National Institute of Standards and Technology), Department of Agriculture, and Department of Veterans Affairs (FLC 2008).

Patent Licenses

A patent license can be exclusive, nonexclusive, or limited by a field-of-use. Companies or individuals who wish to obtain a license for a federally owned invention must first submit a plan for developing and marketing the invention. The submitted plan is treated as privileged and confidential and not subject to disclosure under the Freedom of Information Act (Freedom of Information Act (35 U.S.C. §209(f)). When the federal government grants a license, it is required by statute to reserve a royalty-free license to practice, sometimes called "government-purpose rights" (35 U.S.C. §3710a(b)(2)). Furthermore, if the patent licensee has not taken effective steps toward application and the invention is necessary to alleviate health or safety needs or meet requirements for public use, the government may use its rights to compel the contractor to grant a license to the invention to a responsible party (35 U.S.C. §3710a(b)(1)(B)-(C)). While these rights are a useful tool to encourage licensees to meet these requirements on their own, agencies have not had to invoke these rights to modify a commercial license.

In addition, licensees and sub-licensees may be required to maintain product liability insurance, as well as indemnify the federal laboratory and U.S. government against all claims arising out of the exercise of the license. Based on advice from U.S. Department of Agriculture's Office of General Counsel, USDA has deleted these provisions from their license agreements, in part because the and small businesses may not be able to afford insurance, and are certainly not in a position to indemnify the U.S. Government. The government's liability is limited in any case under the Federal Tort Claims Act. Patent licenses are used by every major agency's laboratories (FLC 2008).

Partnership Agreements

Cooperative Research and Development Agreements

Cooperative Research and Development Agreements (CRADAs) are formal research contracts between federal laboratories and nonfederal entities to advance technologies toward commercial applications. It is an agreement between one or more federal laboratories and one or more nonfederal parties under which the government, through its laboratories, provides personnel, services, facilities, equipment, intellectual property, or other resources with or without reimbursement (but not funds to nonfederal parties) and the nonfederal parties provide funds, personnel, services, facilities, equipment, intellectual property, or other resources toward the conduct of specified research or development efforts consistent with the missions of the laboratory (15 U.S.C. §3710a(d)(1)). Traditional CRADAs are those between a federal laboratory and nonfederal partners, while "non-traditional CRADAs" are used for special purposes, including material transfers, equipment calibrations or other technical assistance where information needs to be protected from disclosure (NIST 2010).

GOGO and GOCO laboratories, including weapon production facilities of the Department of Energy, are authorized to use CRADAs (15 U.S.C. §3710a(d)(2)). CRADA partners may be industry, universities, and nonprofits, but preference is to be given to small businesses and businesses who agree to manufacture the resulting products in the United States (15 U.S.C. §3710a(c)(4)).

Laboratories may grant, or agree to grant in advance, patent licenses or assignments to inventions made by laboratory employees in whole or in part during the course of the agreement. The laboratory must ensure the collaborating party has the option to choose an exclusive license for a pre-negotiated field of use for any such invention (15 U.S.C. §3710a(b)(1)). Patent rights granted to the collaborator are subject to the government's royalty-free license to practice or have practiced on its behalf (15 U.S.C. §3710a(b)(1)(A)).

The laboratory may waive, in advance, any right of ownership to an invention made by the collaborating party, subject to the government's option to claim a license to practice or have practiced on its behalf (15 U.S.C. §3710a(b)(2)). While agencies are allowed to waive this license to practice under the 1996 amendments to Stevenson-Wydler, in practice, the government usually retains it (OTP 2000).

Information developed during a CRADA is protected from disclosure under the Freedom of Information Act (FOIA) or other methods for up to 5 years (15 U.S.C. §3710a(c)(7)). The first federal laboratory to execute a CRADA was the Agriculture Research Service (ARS) within the USDA (OTP 2000). All the major agencies' laboratories now have active CRADAs (FLC 2008).

Clinical Trial CRADA

Clinical Trial CRADAs (CT-CRADAs) allow a laboratory and a partner to collaborate on the development and design of a clinical trial to evaluate the safety and efficacy of an agent. CT-CRADAs are used by the National Institutes of Health and the Department of Veterans Affairs (FLC 2008).

Master CRADAs

Master CRADAs are used for repeat collaborators. They settle intellectual property and other terms up front so that these do not need to be renegotiated for each research project (VA 2010). Master CRADAs are used by the Department of Defense, Department of Energy, and the Department of Veterans Affairs (FLC 2008).

Space Act Agreements

Under the Space Act of 1958, NASA has the unique broad discretion to enter into any agreements that further its objectives. Section 203(c)(5) of the Space Act authorizes NASA to enter any, "*other transactions* as may be necessary in the conduct of its work and on such terms as it may deem appropriate, with any agency or instrumentality of the United States, or…any person, firm, association, corporation, or educational institution (42 U.S.C. §2473(c)(5); emphasis added).

The "other transactions" are commonly referred to as "Space Act Agreements" (SAA). NASA provides the funding for the work in a funded agreement, each party pays its own costs in a non-reimbursable agreement, or the collaborator pays for the work NASA conducts in a reimbursable agreement. Partners may be large entities, universities, other government entities, nonprofits or small businesses, and either domestic or foreign. NASA prefers nonexclusive SAAs but will consider exclusivity in certain circumstances. Under most SAAs, NASA does not acquire title to inventions made solely by the partner (NASA 2008).

Resource Use Agreements

Commercial Test Agreements

Commercial Test Agreements (CTAs) allow partners to use the services of a federal laboratory, center, or test facility to test materials, equipment, models, computer software, CTAs are used by the Air Force (FLC 2008) and the U.S. Army Medical Research and Materiel Command (AMRMC) (U.S. Army Medical Research Acquisition Activity 2009).

Test Service Agreements

The Department of Defense is authorized to sell services for the testing of materials, equipment, models, computer software, and other items under Test Service Agreements (TSAs). TSAs are not intended to be used for research studies nor can they constitute undue competition with the private sector. Partners may be individuals, partnerships, corporations, associations, state, local or tribunal governments, or an agency or instrumentality of the United States, but not agencies of foreign governments (10 U.S.C §2539b).

User Facility Agreements/Facility Use Agreements

User Facility Agreements (UFAs), or Facility Use Agreements for the National Institute of Standards and Technology (NIST) (Lynch 2005), allow outside parties access to the unique research equipment and facilities of federal laboratories. Typically, UFAs allow for fabrication, calibration, testing, and evaluation of products and processes. UFAs are performed and funded by the partner, who retains all patent rights to inventions subject to the government's royalty-free license. Many laboratories retain master UFAs with a number of partners to facilitate access for their employees. The Department of Energy, NIST and Army use UFAs (FLC 2008).

Work for Others

The Work-for-Others (WFOs) agreement is a contract for performance of research, but the research or technical assistance is wholly performed by the federal laboratory and fully funded by the partner entity, rather than being a research "partnership." The "resources" used under a WFO contract include not only the laboratory space and facilities but also the federal researchers, themselves. Partners can be private industry, academia, state and local governments, as well as other federal laboratories or departments. WFOs must draw on unique resources of the laboratory and not directly compete with the private sector. The WFO sponsor may be granted patent rights to any invention developed during the course of the agreement subject to the government's typical nonexclusive royalty free license. As under a CRADA, proprietary data is protected (U.S. Department of Energy 2001). WFOs are only used by the Department of Energy and Department of the Interior (FLC 2008).

Educational Agreements

Educational Partnership Agreements

The laboratories of the Department of Defense are authorized to enter Education Partnership Agreements with educational institutions. Educational institutions include local educational agencies, colleges, universities and other nonprofit institutions. Under an EPA, the laboratory may provide equipment and personnel for instruction at the institution, and allow faculty and students to participate in research projects at the laboratory (10 U.S.C §2194). The Army Research Laboratory reports that the "[b]enefits to the Army are two-fold. First, the university develops scientific and engineering expertise applicable to future Army needs. Second, students working on ARL-sponsored research receive an early exposure to ARL thereby expanding the possible talent pool for future recruitment" (U.S. Army Research Laboratory 2011).

Intramural Research Training Award

Intramural Research Training Awards (IRTAs)—Cancer Research Training Awards (CRTAs) in the National Cancer Institute—are grants for recent college graduates (Post baccalaureate IRTA), graduates of master's programs (Technical IRTA/CRTA), and postdoctoral candidates (Postdoctoral IRTA) to perform research at the National Institutes of Health (NIH 2011a, 2011b). The IRTA program provides opportunities for developmental training and practical research experience in biomedical fields.

Personnel Exchange Agreements

Guest Researcher Agreements

Guest Researcher Agreements are the most common formal partnering agreement used by the National Institute for Standards and Technology and approximately 1500 are put in place each year. The purpose of these agreements is to make NIST facilities available for collaborative R&D projects of interest to both the outside institution and NIST. As such, they can also be considered a cross between a Facility Use Agreement and a CRADA. Partners include researchers from universities, industry, other government agencies, local and state governments, and international institutions (Lynch 2005).

Industrial Staff Member, Assignment or Fellow Agreements

Personnel Exchange Agreements at the Department of Energy can take the form of an Industrial Staff Member Agreement (whereby a company staff member works at the federal laboratory), an Industrial Assignment Agreement (whereby a laboratory staff member works at a company and the company pays the member's entire salary), or an Industrial Fellow Agreement (whereby a laboratory staff member works at a company and the company and laboratory split the cost of the member's salary). There is no protection of proprietary data and intellectual property rights are subject to negotiation (FLC 2008, 2007).

Intergovernmental Personnel Act Agreements

The Intergovernmental Personnel Act (IPA) allows for the temporary assignment of skilled personnel at other federal agencies, state and local governments, institutions of higher education, federally funded research development centers maintained by the National Science Foundation, Indian tribal governments, and other nonprofit organizations without loss of employee rights and benefits. All agencies are covered by the IPA (U.S. Office of Personnel Management 2011).

Agreements with Partnership Intermediaries

Partnership Intermediary Agreements

Partnership Intermediary Agreements (PIAs) are between a nonprofit organization (partnership intermediary) and a federal agency to facilitate technology transfer (15 U.S.C. §3715). Partnership intermediaries provide services, including marketing assessments, business plan development assistance, identification of funding sources, access to facilities, equipment and research expertise through formal agreements, and assistance in technology matching. The Department of Defense and U.S. Department of Agriculture use PIAs (FLC 2008).

Other Agreements with Partnership Intermediaries

The Department of Commerce, Department of Energy, National Institutes of Health, and National Security Agency have other agreements with partnership intermediaries, either formal or informal.

Table C-1. Technology Transfer Mechanisms in Use by Federal Agencies

Mechanisms in Use by Agency		DHS	DOC	DOD	DOE	DOT	EPA	NASA	HHS	USDA	USGS	VA
Invention Protection	Invention Disclosures	X	X	X	X	X	X	X	X	X	X	X
	Patents	X	X	X	X	X	X	X	X	X	X	X
	Copyrights		X		X			X				
Property Transfers	Patent Licenses	X	X	X	X	X	X	X	X	X	X	X
	Material Transfer Agreements (MTA)		X	X					X	X		X
	Email MTAs								X			
Research Partnership Agreements	CRADAs	X	X	X	X	X	X	X	X	X	X	X
	Clinical Trial CRADA			X					X			X
	Master CRADAs			X	X				X			X
	Space Act Agreements							X				
Resource Use Agreements	Commercial Test Agreement			X								
	Facility Use Agreement		X	X								
	Test Service Agreements			X								
	User Facilities Agreement			X	X							
	Work-For-Other Agreements			X	X							
Educational Agreements	Educational Partnership Agreements			X								
	Intramural Research Training Award								X			
Personnel Exchange Agreements	Guest Researcher Agreement		X									
	Industrial Staff Member, Assignment, or Fellow Agreement				X							
	Intergovernmental Personnel Act	X	X	X	X	X	X	X	X	X	X	X
Agreements with Intermediaries	Partnership Intermediary Agreements			X				X		X		
	Other Types of Agreements with Partnership Intermediaries		X	X					X			

Appendix D: Interview Protocol

This appendix contains the discussion instrument that was used to guide discussions with agencies and laboratories included in this study. Prior to each discussion, the guide was adjusted to address specific information about the agencies and laboratories that was gleaned from websites and literature. The discussions were semi-structured; thus, not all questions were asked of each agency and laboratory.

Introduction/Personal Information

Briefly, tell me about your position.

- What is your title?
- How many years have you worked at this position?
- Had you previously worked in technology transfer?
- Where did you work before coming to this position?

Laboratory Characteristics

Is there anything about your laboratory such as history, oversight, budget, legal authorities or research focus that makes it different from other laboratories at your agency?

From your website, it appears that your laboratory does science and engineering in areas X,Y, and Z. Roughly what fraction of your R&D portfolio is devoted to each?

Lab Mission and Technology Transfer Objectives

What is your definition of technology transfer?

- What are the goals of technology transfer under this definition?

The Federal Laboratory Consortium for Technology Transfer lists five models of technology transfer: commercial transfer, exporting resources, importing resources, dual use, and scientific dissemination. Which models best describe technology transfer at your lab?

How does the type of research done at your laboratory affect technology transfer?

- What about technology transfer that leads to commercialization?

- Is there anything particular to the industry-side of this type of R&D that makes technology transfer easier or more difficult?

How does technology transfer fit into achieving your lab's mission?

- Are they ever at odds?
- Is technology transfer integral to or peripheral to your lab's mission?

How important is *commercialization* of technologies to the achievement of your lab's mission?

How has technology transfer at your laboratory changed in the past 5-10 years?

How, if at all, have the following affected your lab?

- New legislation
- Major funding changes
- New oversight/management
- New areas of research

Implementing Technology Transfer

What is your office's mission?

- What are the function and responsibilities of your office?

Does your office have the authority to sign CRADAs, file patents, and negotiate licenses?

- If not, who else is involved?

How centralized or decentralized is technology transfer and technology transfer legal authority within your agency and lab?

How do you implement agency technology transfer policies?

- Are they difficult to implement?
- Have there been any recent policies?
    - Can you provide an example?

Walk us through a typical invention disclosure → patent → licensing process. How are inventions disclosed?

- How does your office know what technologies might have commercial potential? Do inventors alert you of them? Do you have scouts?
- What criteria are used to decide which patents to file? Is there an invention evaluation committee?

- Is it ever the case that an invention is made but could use more work to see if it is patentable? If so, what happens?

How are licensees found for patented technologies?

- How, if at all, does your office provide information on technologies available for licensing at your lab?
- Do you ever contact companies when you have technologies for license?
- Does your office grant exclusive licenses? Does doing so require special authorities?
- Does your office use standard licensing agreements?
- What is your lab's policy towards licensing to the inventor?
- What is your lab's policy towards licensing to start-ups? In what ways, if at all, do licensing agreements with start-ups differ from those to established companies?
- What is your office's patents-filed-to-licenses-granted ratio?

Walk us through a typical CRADA process:

- How are CRADA partners identified?
- Do you use:
  - Model CRADAs?
  - Modular CRADAs?
  - Umbrella/blanket CRADAs?
  - Technical assistance CRADAs?
- If so, to what extent have these been useful?
- How does your laboratory support (monetarily) the work done under a CRADA?
- Do CRADAs typically result in intellectual property?

Walk us through a typical work-for-others process:

- Do you require advance payment? If so, how many days?

Does your office have a specific "commercialization" group?

- If so, what are their functions and responsibilities?

How does your office interact with counsel?

- Do you feel that your objectives are aligned?

How does your office interact with [other offices identified in information sheet]?

- Do you feel your objectives are aligned?
- How do your functions differ?

Industry Interactions

Outside of a typical CRADA or licensing process, how does your office engage industry?

- How do you provide information to them on your R&D activities and outputs?
- Do you have any industry partnerships?
- Who are they?
- What are the benefits of these partnerships?
- Do you interact at all with:
  - Venture Capital/Angel groups?
  - Entrepreneurs?
  - Marketing groups?

Measures

How effective do you think your laboratory has been at transferring technology that leads to commercialization?

How are the metrics collected from your department's laboratories for the Congressional Report?

- Are there any issues around collecting these metrics?
- Are these metrics used internally? If so, how?
- Do you think your lab's technology transfer activities, outputs, and outcomes are reflected accurately in the NIST report?

Beyond the metrics required by Congress, do you collect additional measures of technology transfer?

- Do you collect any internal metrics to track activities?
- Do you collect any output and outcome measures?
- Have you undertaken any studies to look at outcomes?
- Do you track participants of CRADAs, licenses, etc.?

Are there any metrics that you would you like to collect, but do not?

- Why aren't they collected?

How do you evaluate the success of your technology transfer program?

- How do you evaluate technology transfer activities such as CRADAs, licenses, and patents?
- How do you evaluate technology transfer outcomes?
- Are these the same things that you measure when looking at the success of your laboratory as a whole?

How good are technology transfer measures at describing the achievement of your lab's primary mission?

Barriers and Strategies

What barriers inhibit your laboratory from transferring technology that leads to commercialization?

Which of these barriers are insurmountable, a challenge, or something that slows down the process?

- Barriers mentioned in the literature:
  - Technology transfer viewed as outside the scope of the agency mission
  - Technology transfer is an unfunded mandated
  - Researchers may have insufficient expertise or incentive to do technology transfer
  - Labs push technologies instead of responding to market pull
  - Lack of outreach and publicizing inventions to industry
  - Government legal requirements such as conflict of interest and IP rights
  - Length of time for technology transfer negotiations and agreements
  - Requirement for large up-front investment resulting in "valley of death"

Which barrier is the single most important to overcome?

- What would be required to remove that barrier?

What strategies have you implemented for improving technology transfer that leads to commercialization?

- How specifically do these strategies address the barriers?

What one or two specific strategies not already in place would you like to implement?

- What would be required to implement them?

Culture at the Lab

Are researchers allowed to spend time working outside the laboratory for industry?

Are researchers incentivized to participate in technology transfer?

- Are these incentives the same for all types of researchers?
- What is the distribution of income from licensing revenues?
- Does your laboratory offer cash incentive awards to inventors?
- Are technology transfer activities included in researchers' annual performance evaluation?

Are there things that disincentivize researchers from participation in technology transfer?

How supportive of TT is management?

- Is the laboratory director supportive of technology transfer?
- How does your office interact with the laboratory director?

Partnerships

Does your laboratory see itself having a role in the regional economy? If so, what is it?

What types of partnerships, formal or informal, do you have with universities?

- Can you give an example?
- How important are these relationships?
- Types of relationships mentioned in literature review:
  - Use of business and law school students to develop business plans for laboratory technologies
  - MBA internships

What types of partnerships, formal or informal, do you have with partnership intermediaries, or other groups that provide a link between industry and your lab?

- Can you give an example?
  - What is the function of the partnership intermediary?
  - How important are these relationships?
  - Types of intermediaries mentioned in lit review:
    - Venture Capital/Angel groups
    - Entrepreneurships
    - Marketing groups

What types of partnerships, formal or informal, do you have with state and local governments?

- What are the purposes of these partnerships?
- How important are these relationships for technology transfer? What types of partnerships, formal or informal, do you have with other laboratories?
- How do you share best practices between laboratories?
- Do you participate in an agency-wide tech transfer coordination group?
  - What is the purpose of your participation?
- Do you participate in the FLC?
  - What is the purpose of your participation?

Closing

Do you have any other thoughts on technology transfer that we haven't covered so far?

What one or two things could come out of this study that would really help your lab?

Is there anyone else (at the lab, agency, or outside the lab) that you recommend we interview?

- Who and why?

We may do a follow-on study with industry partners. May we speak with some of your industry partners? Can you provide us with contacts?

Have you done any studies related to technology transfer at your lab?

Can we have a copy?

Appendix E: Laboratory Selection Methodology

Overview

This appendix describes the laboratory selection methodology. It first describes how the 26 laboratories were selected. It then compares these laboratories to a list of 180 laboratories drawn from the Federal Laboratory Consortium for Technology Transfer (FLC).[1]

Lab Selection Methodology

Twenty-seven laboratories and twelve agencies and subagencies were interviewed for the study. We attempted to interview all agencies and subagencies with technology transfer representatives. We then purposefully selected 26 laboratories on a variety of characteristics including agency, contractor type, geographic location, budget, and size. In addition, as agency discussions came before laboratory interviews, agency technology transfer representatives were asked for recommendations on laboratories to interview.

To understand how this list of laboratories compares to the general population of laboratories, we compared the 26 selected laboratories to a list based on that of the FLC. At the time of this study, the FLC listed 316 laboratories on their website, which includes all Federal laboratories with an Office of Research and Technology Applications (ORTA).[2] This list was then condensed to be more comparable to the 26 selected laboratories. Multi-site centers with unified or joint missions were combined. In addition, centers that had a science and technology workforce of less than 200 people as well as centers that were used for production, remediation, or that were closed were eliminated. This brought the total to 180 FLC laboratories. It should be noted that several of the laboratories that we selected including NOAA Coastal Environmental Health and Biomolecular Research Laboratory and NOAA Hollings Marine Laboratory were not in this list of FLC laboratories because they do not have large enough workforces. Thus, comparisons should be taken with a grain of salt.

Table E-1 shows the distribution of laboratories by parent agency, comparing between the list of 180 FLC laboratories and the 26 selected interviewed laboratories.

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[1] The FLC is the nationwide network of federal laboratories that provides the forum to develop strategies and opportunities for linking laboratory mission technologies and expertise with the marketplace. http://www.federallabs.org/home/about/.

[2] See http://www.federallabs.org/labs/results/.

STPI under-selected Department of Defense (DOD) laboratories because many DOD laboratories focus on application rather than technology development. STPI over-selected DOE laboratories because many DOE laboratories are GOCO laboratories, and it was desirable to interview a broad range of operator types. Table E-2 compares the operator type between the list of 180 FLC laboratories and the 26 selected interviewed laboratories. Table E-3 compares the BEA region location of laboratories between the list of 180 FLC laboratories and the 26 selected interviewed laboratories.

Table E-1. Comparison of FLC Laboratories and STPI-Selected Laboratories by Agency, 2010

Agency	FLC	FLC %	STPI	STPI %
Department of Homeland Security (DHS)	5	3%	—	—
Department of Commerce (DOC)	4	2%	4	15%
Department of Defense (DOD)	82	46%	4	15%
Department of Energy (DOE)	18	10%	8	31%
Department of the Interior (DOI)	18	10%	—	—
Department of Labor (DOL)	1	1%	—	—
Department of Transportation (DOT)	5	3%	2	8%
Environmental Protection Agency (EPA)	6	3%	—	—
Department of Health and Human Services (HHS)	27	15%	5	19%
National Aeronautics and Space Administration (NASA)	10	6%	2	8%
National Security Agency (NSA)	1	1%	—	—
Department of Agriculture (USDA)	3	2%	1	4%
Department of Veterans Affairs (VA)	—	—	—	—
Total	180	102%[a]	26	100%

Source: List of FLC laboratories was a subset of laboratories from the complete list at http://www.federallabs.org/labs/. Methodology describing selection of subset is described in the text.

[a] Total does not add up to 100% due to rounding.

Table E-2. Comparison of FLC Laboratories and STPI-Selected Laboratories by Operator Type, 2010

Contractor Type	FLC	FLC %	STPI	STPI %
GOGO	161	89%	17	65%
GOCO: Academic	7	4%	2	8%
GOCO: Corporate for profit	5	3%	2	8%
GOCO: Corporate nonprofit	3	2%	2	8%
GOCO: Hybrid	4	2%	3	12%
Total	180	100%	26	101%[a]

Source: List of FLC laboratories was a subset of laboratories from the complete list at http://www.federallabs.org/labs/. Methodology describing selection of subset is described in the text.

Notes: GOGO includes Volpe, which is a GOGO-fee for service. The following definitions were used:

GOCO: Academic – A laboratory or facility that is managed by academic institutions, e.g., NASA-JPL.

GOCO: Corporate for profit –A laboratory or facility that is organized as a for-profit entity and managed by a corporation, e.g., Sandia.

GOCO: Corporate nonprofit – A laboratory or facility that is organized as a nonprofit entity and managed by a nonacademic entity, e.g., PNNL.

GOCO: Hybrid – A laboratory or facility that is managed by multiple types of entities, at least one of which is an academic institution, e.g., ORNL.

[a] Total does not add up to 100% due to rounding.

Table E-3. Comparison of FLC Laboratories and STPI Interviews by BEA Region, 2010

BEA Region	FLC	FLC %	STPI	STPI %
Far West	19	11%	4	15%
Great Lakes	15	8%	2	8%
Mid East	62	35%	10	38%
New England	9	5%	1	4%
Plains	5	3%	—	—
Rocky Mountain	13	7%	2	8%
Southeast	41	23%	5	19%
Southwest	15	8%	2	8%
Total	179[a]	100%	26	100%

Source: List of FLC laboratories was a subset of laboratories from the complete list at http://www.federallabs.org/labs/. Methodology for selection of subset is described in the text.

[a] Total is different because it excludes the Water Science Center as it is listed in all Census regions.

Appendix F: Stakeholder Discussions and Meeting Attendance

STPI performed stakeholder interviews and attended several meetings to (1) get a baseline understanding of technology transfer, (2) gain a better understanding of specific topics related to technology transfer and commercialization, and (3) capture an industry perspective on technology transfer as it related to commercialization. STPI interviewed general stakeholders and attended meetings to accomplish the first two objectives and partnership intermediaries to accomplish the third. The following section provides lists of interviewed stakeholders and attended meetings.

General Stakeholders

Discussions were held with 26 general stakeholders. These stakeholders provided in-depth information in areas of technology transfer and other related topics, and included university technology transfer representatives, academics, and government staff associated with programs such as the National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership (MEP) program. Table F-1 lists general stakeholders interviewed and the subject matter discussed.

Partnership Intermediary Stakeholders

In order to include an industry perspective in our study, STPI also interviewed seven partnership intermediaries, or PIAs. These groups exist to help laboratories partner with industry and are often pre-existing economic development organizations, or angel and venture capital groups. All of the partnership intermediaries that participated in discussions are members of either the Department of Defense (DOD) Office of Technology Transfer Partnership Intermediary Network (OTTPIN) or the U.S. Department of Agriculture (USDA) Agricultural Technology Innovation Partnership (ATIP) program. Table F-2 lists these stakeholders.

Table F-1. List of General Stakeholders

Stakeholders	Subject	Discussion Date
Joseph Allen, Allen & Associates	History of Technology Transfer Policy and Legislation	Jul 23, 2010
Robert Charles, AMRMC	Technology Transfer Legislation	Jul 28, 2010
Gary Jones, FLC	Federal Laboratory Consortium for Technology Transfer (FLC)	Aug. 3, 2010
Rick Shindell, SBIR Gateway	Small Business Innovation Research (SBIR)	Aug 19, 2010
Jon Soderstrom, Yale	Federal Laboratory and University Technology Transfer	Sep 22, 2010
Lisa Kuuttila, University of New Mexico	Commercialization and Marketing	Sep 23, 2010
John Hyrn, ANL	Argonne National Laboratory	Sep 29, 2010
Paul Zielinski, NIST	Interagency Working Group for Technology Transfer (IWGTT)/Summary Report	Oct 28, 2010
Mark Boroush, NSF	Technology Administration	Nov 8, 2010
Drew Bond, Battelle	Battelle/ Energy Efficiency and Renewable Energy	Nov 10, 2010
Leonard Buckley, IDA	Naval Research Laboratory	Nov 9, 2010
Clara Asmail, NIST MEP	SBIR-TT	Nov 30, 2010
Brett Bosley, Battelle	Battelle	Dec 2, 2010
Wendolyn Holland, EERE	Energy Efficiency and Renewable Energy (EERE)	Dec 10, 2010
Bill Valdez, DOE	STAR METRICS	Dec 13, 2010
Kevin Kelleher, NSSL	NOAA National Severe Storms Laboratory	Dec 13, 2010
John Morris, Center for Entrepreneurial Growth	Technology 2020	Dec 14, 2010
Alexander "Sandy" McDonald, OAR and ESRL	NOAA Office of Oceanic and Atmospheric Research (OAR)	Dec 19, 2010
Nancy Vorona, CIT	Center for Innovative Technology (CIT)	Dec 20, 2010
Carl Gulbrandsen, WARF	Wisconsin Alumni Research Foundation (WARF)	Jan 4, 2011
Patrick Jones, University of Arizona	Privately Funded Technology Transfer	Jan. 6, 2011
Cherie Nichols, Johns Hopkins	INNoVATE	Jan 11, 2011
Jim Turner	Copyright Law	Feb 10, 2011
Mark Skinner, SSTI	Regional Innovation Acceleration Network	Feb 11, 2011
Robert Samors, APLU	Association of Public and Land-Grant Universities (APLU)	Feb 15, 2011
Dana Bostrom, AUTM	Association of University Technology Managers (AUTM)	Mar 4, 2011

Table F-2. List of Partnership Intermediaries

Partnership Intermediaries	Discussion Date
FirstLink	Dec 13, 2010
Kansas Bioscience Authority	Dec 7, 2010
MilTech	Dec 8, 2010
NASVF (National Association of Seed and Venture Funds)	Dec 2, 2010
TechComm	Jan 6, 2011
TechLink	Nov 17, 2010
TEDCO	Jan 19, 2010

Meeting Attendance

In addition to the background report and interviews with laboratories, agencies, partnership intermediaries, and other stakeholders, STPI attended several meetings related to technology transfer. These meetings helped to ground the background report. They also gave STPI the opportunity to interact personally with ORTA officers and other important stakeholders. In total, STPI attended the seven meetings listed in Table F-3.

Table F-3. STPI Meeting Attendance

Date	Meeting
Sep 20–22, 2010	FLC Northeast 2010 Region Meeting
Oct 5–7, 2010	FLC Mid-Atlantic 2010 Region Meeting
Oct 13–15, 2010	National Association of Seed and Venture Funds Annual Conference
Oct 19, 2010	FLC Executive Board Meeting
Nov 2–3, 2010	DOE Technology Transfer Working Group
Nov 12–13, 2010	Tech Transfer Society Annual Conference
Jan 12, 2011	Tech Transfer Speaker Series—Maryland TEDCO

Appendix G: Metrics Collected by Agencies

This appendix lists the metrics given in the summary report to the President and Congress that describes federal technology transfer and compares this to other metrics that are collected by individual departments and agencies.[1]

Summary Report Metrics

Collaborative Research

- CRADAs, Total Active in FY
- CRADAs, New Executed in FY
- Traditional CRADAs, Total Active in FY
- Nontraditional CRADAs, Total Active in FY
- Other Collaborative R&D Relationships

Invention Disclosure and Patenting

- New Inventions Disclosed in FY
- Patent Applications Filed in FY
- Patents Issued in FY

Active Licenses

- All Licenses, Total Active in FY
- All Licenses, New Executed in FY
- Invention Licenses, Total Active in FY
- Invention Licenses, New Executed in FY
- Other IP Licenses, Total Active in FY

[1] For a description of the summary report, refer to Chapter 6 of the main text.

Characteristics of Licenses Bearing Income

- All Income Bearing Licenses
- Exclusive Licenses Bearing Income

Income from Licensing

- Total Income, From All Licenses Active in FY
- Income, From Invention Licenses Active in FY
- Income, From Other IP Licenses Active in FY
- Total Earned Royalty Income

User Facilities and Work for Others

- No Reported Metrics

Start-ups

- No Reported Metrics

Products Commercialized

- No Reported Metrics

Human Capacity

- No Reported Metrics

Scientific Dissemination

- No Reported Metrics

Agency Specific Measures

- No Reported Metrics

DOC—Department of Commerce

The metrics below are those reported in the Department of Commerce's "Summary Report on Technology Transfer: Approach and Plans, Fiscal Year 2009 Activities and Achievements" available at: http://www.nist.gov/tpo/publications/upload/2009-Tech-Transfer-Rept-FINAL.pdf. Metrics are reported for Institute for Telecommunications Sciences (ITS), National Institute of Standards and Technology (NIST), and National Oceanic and Atmospheric Administration (NOAA).

Collaborative Research

- Traditional CRADAs, New Executed in FY
- Nontraditional CRADAs, New Executed in FY
- Collaborative Contributions (ITS Only)

Invention Disclosure and Patenting

- Active Patents, End of FY

Active Licenses

- Material Transfer Licenses (Inventions), Total Active in FY
- Material Transfer Licenses (Inventions), New Executed in FY
- Material Transfer Licenses (Non-inventions), Total Active in FY
- Material Transfer Licenses (Non-inventions), New Executed in FY
- Copyright Licenses (Fee-Bearing), Total Active in FY
- Copyright Licenses (Fee-Bearing), New Executed in FY
- Average, Minimum, and Maximum License Negotiation Time of Licenses Granted in FY
- Licenses Terminated for Cause

Characteristics of Licenses Bearing Income

- Partially Exclusive Licenses Bearing Income
- Nonexclusive Licenses Bearing Income

Income from Licensing

- Median, Minimum, and Maximum Earned Royalty Income
- Earned Royalty Income from Top 1 percent, Top 5 percent, and Top 20 percent of Licenses

User Facilities and Work for Others

- Facility Use Agreements (NIST only)
- Number of Calibration Tests Performed (NIST only)

Human Capacity

- Guest Scientists and Engineers (NIST only)

Scientific Dissemination

- Standard Reference Materials Available (NIST only)
- Standard Reference Materials Sold (NIST only)
- Standard Reference Data Titles Available (NIST only)
- Technical Publications in Peer-Reviewed Journals (NIST only)
- Journal Articles Published (NOAA only)
- Technical Reports Published (NOAA only)
- Technical Publications Produced (ITS only)

DOD—Department of Defense

From "Technology Transfer Achievements" reported at: http://www.acq.osd.mil/ott/techtransit/crada_accomp.html and http://www.acq.osd.mil/ott/techtransit/pla_accomp.html.

Collaborative Research

- CRADAs by State/Territory of Non-Federal Partner
- CRADAs by State/Territory of Federal Partner

Active Licenses

- Patent License Agreements by State/Territory/Country of Non-Federal Partner, Total Active
- Patent License Agreements by State of Federal Partner, Total Active

DOE—Department of Energy

The following metrics are collected through the DOE's metrics manual. This manual is currently under revision, and so this list may not represent the most up-to-date list of metrics collected by the DOE.

Collaborative Research

- Actual CRADA Funds-In
- Active CRADAs with Small Businesses

Invention Disclosure and Patenting

- U.S. Patent Applications Filed
- Foreign Patent Applications Filed
- U.S Patents Issued
- Foreign Patents Issued
- Total Copyright Assertion Requests

Active Licenses

- Total Nonfee-Bearing Licenses, Total Active in FY and New Executed in FY
- Total Fee-Bearing Licenses, Total Active in FY and New Executed in FY
- Nonfee-Bearing Patent Licenses, Total Active in FY and New Executed in FY
- Fee-Bearing Patent Licenses, Total Active in FY and New Executed in FY
- Nonfee Bearing Copyright Licenses, Total Active in FY and New Executed in FY
- Fee Bearing Copyright Licenses, Total Active in FY and New Executed in FY
- Nonfee-Bearing Material Transfer Agreements, Total Active in FY and New Executed in FY
- Fee-Bearing Material Transfer Agreements, Total Active in FY and New Executed in FY
- Nonfee-Bearing Bailments, Total Active in FY and New Executed in FY
- Fee-Bearing Bailments, Total Active in FY and New Executed in FY
- Nonfee-Bearing Trademark Licenses, Total Active in FY and New Executed in FY
- Fee Bearing Trademark Licenses, Total Active in FY and New Executed in FY

Characteristics of Licenses Bearing Income

- Total Active Fee Bearing Patent Licenses
- Total Active Fee Bearing Copyright Licenses
- Total Active Fee Bearing Other Licenses
- Total Active Exclusive Fee Bearing Patent Licenses
- Total Active Exclusive Fee Bearing Copyright Licenses
- Total Active Exclusive Fee Bearing Other Licenses
- Total Active Non-Exclusive Fee-Bearing Licenses

Income from Licensing

- Other License Income
- Total Earned Royalty Income from Patent Licenses
- Total Earned Royalty Income from Copyright Licenses
- Total Earned Royalty Income from Other Licenses

User Facilities and Work for Others

- Active Non-Federal Sponsor Agreements
- New Non-Federal Sponsor Agreements
- Active Non-Federal Sponsor Agreements with Small Businesses
- Active Non-Federal Sponsor Agreements with Foreign Sponsors
- Non-Federal Sponsor Agreement Funding
- Active Proprietary User Facility Agreements
- Active Non-Proprietary User Facility Agreements
- Active Deployment User Facility Agreements
- Total Active User Facility Agreements
- User Projects Awarded
- U.S Users
- Foreign Users
- Total Users

Start-ups

- Number of Start-up Companies

Products Commercialized

- Commercialized Technologies

Human Capacity

- Personnel Exchanges Initiated

Scientific Dissemination

- Free Software Products Provided
- Open Source Products Available for Licensing

- Downloads or Distribution of Open Source Products
- Technical Scientific Results Published
- Science Education Activities Performed

DHS—Department of Homeland Security

The following metrics were as reported by the DHS ORTA.

- DHS collects only the required metrics.

DOI—USGS

The following metrics were as reported by the USGS ORTA.

Collaborative Research

- Organic Act Agreements

Active Licenses

- Timeline to Reach License Agreement

User Facilities and Work for Others

- Technical Assistance Agreements

DOT—Department of Transportation

The following metrics were as reported by the DOT ORTA.

- DOT collects only the required metrics.

EPA—Environmental Protection Agency

The following metrics were as reported by the EPA ORTA.

- EPA collects only the required metrics.

HHS—Department of Health and Human Services—National Institutes of Health

The following metrics are those reported on the NIH website: http://www.ott.nih.gov/ttmetrics/default.aspx.

Collaborative Research

- Material CRADAs, Total Active in FY
- Material CRADAs, New Executed in FY

Invention Disclosure and Patenting

- CRADA-related Inventions

Active Licenses

- Biological Materials License—Commercial
- Biological Materials License– Internal Use
- Commercial Evaluation License
- Inter-Institutional Agreement License
- MOU License
- Patent License—Commercial
- Patent License—Internal Use
- Settlement License
- Software License
- Licensees by Business Type (U.S. Government, Large Business, Small Business, Non-Profit, Small U.S. Business, Small Non-U.S. Business, University, Non-U.S.)
- First-time Licensees by Business Type (U.S., Small Business)

Income from Licensing

- Royalty Income By Type—Earned Royalties on Sales, Execution Royalties, Milestones/Benchmarks, Minimum Annual, Royalties, Patent Prosecution, Consideration

Products Commercialized

- Products Development Pipeline—Products in Phase I
- Products Development Pipeline—Products in Phase II
- Products Development Pipeline—Products in Phase III
- Products Development Pipeline—Products in NDA
- Products Development Pipeline—Products on Market

NASA—National Aeronautics and Space Administration

NASA is in the process of implementing a new management system to be used across their centers for collecting and reporting metrics. At present, they do not collect any additional metrics beyond those reported in the summary report.

USDA—Department of Agriculture

The following metrics are as reported in "U.S. Department of Agriculture Summary Reporting on Technology Transfer, FY2009," available at: http://www.ars.usda.gov/sp2UserFiles/Place/01090000/USDAFY2009AnnualReportonTechnologyTransferreleased7July2010FinalNSSEPT.pdf.

Collaborative Research

- Non-Traditional CRADAs, New Executed in FY
- Material Transfer CRADA, Total Active in FY
- Material Transfer CRADA, New Executed in FY
- Master CRADA, Total Active in FY
- Master CRADA, New Executed in FY
- Multiple Cooperation, Total Active in FY
- Multiple Cooperation, New Executed in FY
- Foreign CRADA, Total Active in FY
- Foreign CRADA, New Executed in FY
- CRADA Amendments
- Confidentiality Agreements

Invention Disclosure and Patenting

- Provisional Patent Applications Filed
- Non-Provisional Patent Applications Filed

Active Licenses

- Material Transfer (Invention) Licenses, Total Active in FY
- Material Transfer (Invention) Licenses, New Executed in FY
- Elapsed Execution Time
- Licenses Terminated for Cause

Characteristics of Licenses Bearing Income

- Partially Exclusive Licenses Bearing Income
- Non-Exclusive Licenses Bearing Income
- Partially Exclusive Material Transfer (Invention) Licenses Bearing Income
- Exclusive Material Transfer (Invention) Licenses Bearing Income
- Non-Exclusive Material Transfer (Invention) Licenses Bearing Income

Income from Licensing

- Median, Minimum, and Maximum Earned Royalty Income, By License Type
- Earned Royalty Income from Top 1 percent, Top 5 percent, and Top 20 percent of Licenses, By License Type
- Distribution of Royalties, to Inventors, for Patent Filing Fees, for Other Tech Transfer Expenses

Scientific Dissemination

- Material Transfer Agreements
- Scientific Germplasm Releases (Public and Protected)

VA—Department of Veterans Affairs

The following metrics were reported by the VA's ORTA as being collected in addition to the metrics collected for the summary report.

Collaborative Research

- CRADA Funds-in

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14. ABSTRACT

While the topic of technology transfer from the federal laboratories has been studied at length by academic researchers, many of the studies were completed before 2000, and substantial changes have occurred since then in the national and global economic landscape. Furthermore, past studies examined a small subset of agencies' laboratories, minimizing the broad range of technology transfer. This study encompasses a literature review, discussions with technology transfer personnel at federal agencies and laboratories, and stakeholders at other organizations. From these discussions, we gained an understanding of technology transfer and commercialization activities at the laboratories, identified perceived barriers to technology transfer, and uncovered strategies with potential for overcoming these barriers.

15. SUBJECT TERMS

Commercialization, Technology Transfer, Federal Laboratories, Stevenson-Wydler Act, Space Act Agreements, Office of Research and Technology Applications (ORTAs), Government-Industry Interactions, Researcher Roles, Partnership Intermediary Agreements, Metrics, CRADAs, Commercial Test Agreements, Material Transfer Agreements, Education Partnership Agreements, Federal Labs Consortium, Dual Use, Invention Disclosures, Patents, Commercialization Assistance Programs, Entrepreneurship-in-Residence Programs

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