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THE APPLICATION OF SYSTEMS ENGINEERING/SYSTEMS ARCHITECTURE PRACTICES AND TECHNOLOGY TRANSFER TO SHORTEN DOD ACQUISITION CYCLES

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THESIS

THE APPLICATION OF SYSTEMS ENGINEERING/ SYSTEMS ARCHITECTURE PRACTICES AND TECHNOLOGY TRANSFER TO SHORTEN DOD ACQUISITION CYCLES

by

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September 2019

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ABSTRACT

Department of Defense acquisition life-cycle time frames can be improved through the use of technology transfer activities and industry partners, but only if increased rigor is applied to technology transfer processes. The application of systems engineering and systems architecture practices to current and previously described technology transfer methods has been studied in the literature, and new methodologies have been described. The result is an improved technology transfer process that increases knowledge sharing and reduces the risk realized by commercialization partners. Implementation of these techniques will improve efficiencies within federal technology transfer offices and make government-developed technologies available to the warfighter with shortened acquisition times through the commercial market. Improving government-industry partnerships will provide real benefits to the warfighter, the government research base, and the overall commercial economy of the United States.

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LIST OF ACRONYMS AND ABBREVIATIONS

ASR	alternative system review
AHP	analytical hierarchy process
CV	capability viewpoint
CNO	Chief of Naval Operations
COTS	commercial off the shelf
CRADAs	cooperative research and development agreements
DLE	defense laboratory enterprise
DoD	Department of Defense
DoDAF	Department of Defense Architecture Framework
EMD	engineering and manufacturing development
EOD	explosive ordnance disposal
FTTA	Federal Technology Transfer Act
FRP	full rate production
FBI	Federal Bureau of Investigation
GUI	graphical user interface
IED	improvised explosive device
ITR	initial technical review
IEB	Invention Evaluation Board
IRAD	internal research and development
JVSOs	joint ventures spinouts
LRIP	low rate initial production
MSP	Massachusetts State Police
MSA	materiel solution analysis
MBSE	model-based systems engineering
MINEWAR	mine warfare
NAVAIR	Naval Air Systems Command
NSWC IHEODTD	Naval Surface Warfare Center Indian Head Explosive Ordnance Disposal Technology Division
NJSP	New Jersey State Police
NPD	new product development

NSN	national stock number
NYPD	New York City Police Department
OAI	Office of American Innovation
ORTA	Office of Research and Technology Applications
OV	operation viewpoint
PAN	percussion actuated nonelectric
PEO	Program Executive Officer
PIAs	partnership intermediary agreements
PLAs	patent license agreements
ROSE	relational oriented systems engineering
R&D	research and development
ROI	return on investment
SWaP	size, weight, and power
SBIR	small business innovation research
SBTT	small business technology transfer
SETRS	systems engineering technical reviews
SV	systems viewpoint
SVR	system verification review
TTPs	tactics, techniques and procedures
TRB	Technical Review Board
T2	technology transfer
TTO	Technology Transfer Office
TRL	technology readiness level
T&E	test and evaluation
TTDSE	traditional top-down systems engineering
USC	United States Code

EXECUTIVE SUMMARY

The goal of technology transfer is to provide U.S. citizens a benefit by commercializing the products of federal research efforts that are funded through taxpayer dollars. Recent years have seen an increased desire to improve the efficiency of and return on investment realized from federal technology transfer efforts. However, federal laboratory technology transfer offices are often under staffed and underfunded, and focus their efforts on the protection of intellectual property over marketing and commercialization.

Systems architecture and systems engineering techniques and tools can be exploited by technology transfer offices to provide increased knowledge sharing and improved marketing. The benefits of increased knowledge sharing for research institutions is well documented and demonstrates increased R&D output. Additionally, the models and viewgraphs of systems architecture and model-based systems engineering provide a simple platform for discussing the functional and operational capabilities of government developed technology for commercialization purposes. These simple platforms can help to readily describe the technologies for marketing and market research purposes. Additionally, decompositions allow for the analyses of subcomponent technologies, and can provide for sensitivity analyses.

The rigor of Department of Defense systems engineering practices can also be applied to establish a technology transfer methodology that can be employed within federal laboratories to improve technology transfer activities. By employing the rigor of systems engineering technical reviews within a stage and gate new product development methodology, GO AHEAD and KILL decisions can be made earlier in the technology transfer process, and they will be better informed. This will increase efficiency and reduce unnecessary costs.

Systems architecture and systems engineering are already widely employed disciplines within most federal laboratories. The tools and techniques are well understood and easy to employ. By exploited these tools within the technology transfer process,

technology transfer offices will benefit from inexpensive and easily accessible tools that can improve both efficiency and return on investment.

Additionally, the use of model-based systems engineering techniques can allow for the use of pre-existing market analysis models. This information, when combined with the additional information provided through more conventional means of market analysis can greatly reduce the risk realized by potential commercialization partners. This allows for more successful new product launches, resulting in greater benefit to the taxpayer as well as a boost to the economy.

This body of work describes three programs established within the Department of Defense. Technology transfer activities associated with these programs are also described. Analysis of these case studies provides indication that DoD programs leveraging technology transfer activities stand a greater chance of succeeding. Additional analysis also indicates that these programs are, overall, less expensive than traditional defense acquisition programs. These case studies would indicate a strong benefit for a program to participate in technology transfer activities.

Future work should look to establish a technology transfer program that brings together the tools provided by systems engineering and systems architecture, the technical rigor of a stage and gate technology transfer and new product development methodology, and the Small Business Innovative Research Program. A synergistic effort within this business space could provide increased return on investment and best stewardship of the taxpayer dollar.

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I. INTRODUCTION

A. INTRODUCTION

It has clearly been a trend over the past several decades that technology advancement occurs at a greater pace in the private sector than in the federal laboratory system (Hoover Institute, Stanford University 2019). This is, of course, not true of all technologies but has certainly been demonstrated in several sectors. Private industry's ability to refocus more dynamically and to acquire starting materials rapidly, and its increased flexibility in addressing requirements provide them with a platform that better allows for the iterative prototyping and design capability needed to rapidly advance the technology readiness level (TRL) of systems.

If the Department of Defense (DoD) is to outpace the technology advancements made by near-peer adversaries, it becomes necessary for the federal laboratory system to explore the opportunities available to reduce DoD acquisition times through partnerships with private industry. Additionally, since small- and medium-sized businesses provide the foundation for growth in the United States economic system, government laboratories should make a best effort to focus these partnerships in the small- and medium-business areas of the private sector (Jagoda, Maheshwari, and Lonseth 2010, 366). Strategic partnerships of this type will allow for shortened acquisition times, strengthen the economy, continue to provide the highest quality technology-based systems to the warfighter, and to provide for best stewardship of the taxpayer's dollar.

B. BACKGROUND

DoD laboratories are already tasked by federal law with the mission of transferring government developed technologies into the private sector to provide a maximum benefit to the taxpayer. Specifically, the U.S. Federal Technology Transfer Act of 1986 (Public Law 99-502, 20 OT 1986, as amended), or Title 15 U.S. Code, Section 3710 states that technology transfer is "a responsibility of each laboratory science and engineering professional" (Federal Technology Transfer Act of 1986). It also establishes an Office of Research and Technology Applications (ORTA) and requires that each federal laboratory with 200 full-time equivalent researchers (scientist, engineers, and technicians) provide one or more full-time equivalent positions to staff the ORTA (Federal Technology Transfer Act of 1986).

Federal law also establishes specific tools that are made available to the ORTA to facilitate technology transfer activities. Some of these tools include the use of license agreements, partnership intermediary agreements (PIAs), and cooperative research and development agreements (CRADAs). The 15 USC 3715 authorizes and defines the use of PIAs, as per the National Defense Authorization Act for Fiscal Year 1991, and 15 USC 3710a authorizes and defines the use of CRADAs, as per the Stevenson-Wydler Technology Transfer Act of 1980. Following the Stevenson-Wydler Technology Transfer Act of 1980, CRADAs on technology transfer from federal laboratories to United States industry were legislatively stimulated by the Federal Technology Transfer Act of 1986 (Bernard 1996). Under this act, federal laboratory employees were allowed to share in royalties earned when their innovations resulted in new products after the technology is transferred to the private sector (Bernard 1996). Despite the efforts of the Stevenson-Wydler Technology Transfer Act of 1986, federal employees were not motivated by financial rewards to work on CRADAs; rather they were motivated by the belief that their innovations would be good for the nation, good for their laboratory, and satisfying to their chain of command (Bernard 1996). However, although these tools are made available to technology transfer offices, there is no set methodology to facilitate the technology transfer process. Each federal laboratory executes its technology transfer (T2) program in different ways.

An in-depth study of this, and the effect it has on technology transfer activities, is provided by Tello, Latham, and Kijewski (2010) This study denotes the lack of shared decision-making practices among academic technology transfer offices (TTOs), and the fact that many of the decisions made are based on an individual’s heuristics and biases. Furthermore, it identifies the need for an increase in both understanding and monitoring how these the technology transfer decisions are being made to improve performance within the TTO.

The two most recent presidential administrations have also called for improved performance in federal technology transfer. In both 2011 and again 2018, the administrations called for federal laboratories to increase the return on investment (ROI) of technology transfer activities (Obama 2011; Trump 2018). The Obama administration strived, "to establish goals and measure performance, streamline the administrative processes, and facilitate local and regional partnerships in order to accelerate technology transfer and support private sector commercialization" (Obama 2011, Sec. 2). Additionally, President Obama established the Interagency Workgroup on Technology Transfer, established pursuant to Executive Order 12591 of April 10, 1987, to "recommend to the Department of Commerce opportunities for improving technology transfer from federal laboratories." The presidential memorandum directed an assessment of effectiveness of existing technology transfer programs and standards, called for "new or creative approaches to technology transfer that might serve as model programs for Federal laboratories," called for the "criteria to assess the effectiveness and impact on the Nation's economy," and required an assessment of existing CRADA programs (Obama 2011). The Obama memorandum stated,

> streamlining licensing procedures, improving public availability of federally owned inventions from across the federal government, and improving the executive branch's small business innovation research (SBIR) and small business technology transfer (SBTT) programs based on best practices will accelerate technology transfer from federal laboratories and other facilities and spur entrepreneurship. (Obama 2011, Sec. 3)

President Trump established the White House Office of American Innovation (OAI) on March 27, 2017 to, "make recommendations to the President on policies and plans that improve government operations and services" (Trump 2017, para. 1). Following the establishment of the OAI, the Trump administration released the President's Management Agenda in 2018. One of the priorities this agenda outlined was the improvement to transfer of federally funded technologies from lab-to-market (Trump 2018). To do this, the agenda stated three goals: to "improve the transition of federally funded innovations from the laboratory to the marketplace by reducing the administrative and regulatory burdens for technology transfer," to "develop and implement more effective partnering models and technology transfer mechanisms for federal agencies," and finally, to “enhance the effectiveness of technology by improving the methods and evaluating the ROI and economic and national security impacts of federally funded research and development” (Trump 2018). This has led to recent calls from the federal laboratories to improve the metrics against which the technology transfer office production is measured (Choudhry and Ponzio 2019).

This thesis describes and explores practices and methodologies that can be employed within federal TTOs to improve productivity. Proper implementation of these techniques can not only improve technology transfer performance, but also serve to reduce DoD acquisition times, and continue to maintain the high standards for technology development that are expected within the federal government. These techniques address three basic principles, increasing knowledge sharing between federal laboratories and commercialization partners (with an emphasis on small businesses and start-ups), employing readily available tools to facilitate low cost technology marketing, and employing a technology transfer strategy that is aligned to the methodologies employed by private industry partners for new product development (NPD). The industry NPD practice to which this strategy aligns is the Stage and Gate process developed by Cooper in the late 1970s and 1980s, and follow-on Stage-Gate methodologies. (Cooper 1988; Jagoda, Maheshwari, and Lonseth 2010; Grönlund, Sjödin, and Frishammar 2010) As the literature demonstrates, although Cooper’s Stage and Gate processes was originally developed to reduce risk in NPD efforts, it quickly expanded into areas such as T2 and Innovation. (Jagoda, Maheshwari, and Lonseth 2010; Grönlund, Sjödin, and Frishammar 2010)

In addition to a business strategy, this thesis will explore the use of common DoD techniques for the purposes of increased knowledge sharing with partners and potential partners; and improved, low-cost marketing. These tools should be employed to lower the risk of private industry partners working in collaboration with federal laboratories and to improve their understanding of the technologies being made available for transfer. Additionally, these techniques are commonly employed within, and derived from, systems engineering and systems architecture; and therefore, they are already commonly employed within the DoD and other federal laboratories. This provides the TTO access to on-site subject matter expertise.

Brill notes that the term “systems engineering” was first used by Bell Laboratories in the 1940s, and that the first attempts at formal education were made in 1950 at the Massachusetts Institute of Technology (Brill 1998, 260). Furthermore, although the origins of systems engineering cannot be precisely traced, he credits the development of post-World War II weapons systems with the origins of modern systems engineering. (Brill 1998, 258–260). Additionally, Parnaby and Towill (2009, 916) describe a system as “a related set of elements which are required to work together in an integrated way to achieve a common purpose.”

Modern systems engineering techniques include model-based systems engineering (MBSE) and traditional top-down systems engineering (TTDSE). Model-based systems engineering applies systems models in support of analysis, specification, design and verification efforts, and the output of MBSE activities is a coherent model of the system which can be refined and allowed to evolve. (Friedenthal, Moore, and Steiner 2015, 15–17) TTDSE begins with an analysis of what issue needs to be resolved, and each layer of the decomposition process is verified against the derived requirement (Kamrani and Azimi 2011, 13).

Maier (2009), in his preface to *The Art of Systems Architecture*, third edition, makes the reasonable assumption that if architectural methods are being used to create and build complex systems, albeit unknowingly by the builders, then other architectural tools and ideas should be even more valuable (xv). He identifies a few of these tools as qualitative reasoning and the relationship between client, architect, and builder. He notes that in the time between the first and third editions of his text, architectural concepts have become common in systems engineering discussions. (Maier 2009, xv) However, he distinguishes systems architecture from systems engineering. While engineering relies on measurables using analytical tools, systems architecting deals with unmeasurable using nonquantitative tools based on practical lessons learned. In other words, systems engineering is a deductive process, while systems architecture is inductive (Maier 2009, xvi).

While many systems engineers and architects are employed within the federal laboratory system, there have been few publications written that address the application of systems engineering and systems architecture tools and skills as applied toward the mission of technology transfer. In fact, the authors could find no publications that directly address this topic. However, there is a body of research that does address the importance of technology transfer as it applies to private industry. This body of work describes the importance of technology transfer activities across a broad topic area including (but not limited to): small, medium, and large companies; developing and third world countries; and the law enforcement and first responder communities. Additionally, this body of research describes methodologies that can be used by private companies to maximize the benefit of technology transfer activities within the corporate structure, such as Stage-Gate type processes.

There are already several programs in existence that are designed to develop a business case analysis of an existing technology, with the purpose of describing its potential market space. Many of these programs have proven highly successful for private industry. It is not the authors' intent to replace these programs, but rather to add an increasing fidelity to the information provided to the partnering company. The methodologies described herein will be aligned to the business practices and structures that are described in the literature, and allow the federal laboratory partners a means to develop a coherent package that describes not only the market analysis, but the architecture of the technology and the requirements to which it was built. This will allow industry partners, those who are interested in participating in technology transfer, to more easily understand and evaluate the technology, not only for market share but for additional uses and opportunities for technology advancement. It will ease negotiations between the federal and private partners and provide for more opportunities to advance the TRL of the technology rapidly in the private sector. These practices will also provide for low-cost marketing of federal technologies, as well as marketing the laboratories themselves. Since these systems are based in intellectual property owned by the federal government, it also allows the advanced systems to be "spun in" after technology advancement, providing additional capabilities to the warfighter at a more rapid pace, but at low cost. This can then serve as a best practice to maximize the use taxpayer dollars, while providing economic growth in the private sector.

The authors will present a means by which system elements, or subsystems, can be decomposed and analyzed to reduce the risk to which a private industry partner is exposed in undertaking a NPD effort based on a DoD-developed technology. The intention is to provide the industry partner with an increased understanding of the function of each subsystem, against what requirements that subsystems was designed, and how that subsystem supports the overarching system mission. This will allow for private industry to partner to rapidly advance the capability of the system by adding to or altering the technology of the system elements or to change the system elements to meet a different set of requirements.

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II. LITERATURE REVIEW

A. LITERATURE PRECEDENT

To support the methods described in this thesis, the authors will study two current, Navy developed and patented technologies and conduct a case study of a third Navy patented technology that is currently undergoing commercialization. The choice of a case study is supported by Robert Yin in his book *Case Study Research Design and Methods* (1994). In his book, Yin mentions several methods of performing social science research. Along with case studies, these methods include "experiments, surveys, histories, and the analysis of archival information" (Yin 1994, 1). Each of these methods have inherent benefits, depending upon certain conditions. These conditions are "(a) the type of research question, (b) the control an investigator has over actual behavioral events, and (c) the focus on contemporary as opposed to historical phenomena" (Yin 1994, 1). In a situation when "how" or "why" questions are being posed, or when it is difficult for the investigator to retain control over the events, or if there is a focus current, actual events; Yin stresses that case studies are the preferred strategy, as a general rule (1994, 1).

It is also necessary to understand the Stage-Gate process, and the theories behind it, as well as other industry practices and experiences; as the methods presented here will work in parallel and support these commercial processes by pushing information to the commercialization partner at strategic points in the NPD effort. Additionally, the authors will discuss the current literature regarding the numerous benefits realized by private industry through increased knowledge sharing with academia, peers, and even competitors as well as topics such as technology selection and marketing practices.

B. STAGE-GATE PROCESS

The Stage-Gate process can be traced back to Robert Cooper. In order to determine what distinguishes a successful innovation from a non-successful innovation, Cooper began an investigation in which he studied a series of large samples of unsuccessful and successful new industrial products in 1977. This study encompassed hundreds of new products and firms and tested a number of hypotheses. The result of Cooper's work was a tool for new product managers in the form of a project or process guide for (Cooper 1988, 239–240).

1. Cooper's Model

Cooper's research examined 13 of the key activities that, in his opinion, most often comprise a new product process, as employed within private industry. However, what initially stood out was how often key activities were missing from new product processes. For example, one study of 203 new products showed that there had been no market study and that no detailed market research had been performed in 75% of the new product efforts. This is striking because the same study indicated 20 percent more successes than failures when a preliminary market assessment had been carried out (Cooper 1988, 240–241).

Cooper's research also identifies the need for evaluation points, or "Gates." These Gates serve two major functions according to Cooper. The first of the functions is that the gate can serve as a point where a "GO", ”KILL", or "HOLD" decision can be made. Secondly, they serve as checkpoints to evaluate the quality of the execution of process activities. According to Cooper, each Gate should have its own set of criteria and measures for passing that Gate (Cooper 1988, 240–241).

The conclusion of Cooper's effort is the establishment of a systematic new product process, which is now known as: Stage-Gate Process. A model of the Stage-Gate Process can be seen in Figure 1. This process consists of six main stages and six main gates. These stages and gates consist of: Gate 1: Initial Screening, Stage 1: Assessment, Gate 2: Preliminary Assessment, Stage 2: Definition, Gate 3: Pre-Development Business Analysis, Stage 3: Development, Gate 4: Pre-Test Review, Stage 4: Testing, Gate 5: Pre-Trial Review, Stage 5: Trial, Gate 6: Pre-Commercialization Business Analysis, Stage 6: Commercialization (Cooper 1988, 250–254).

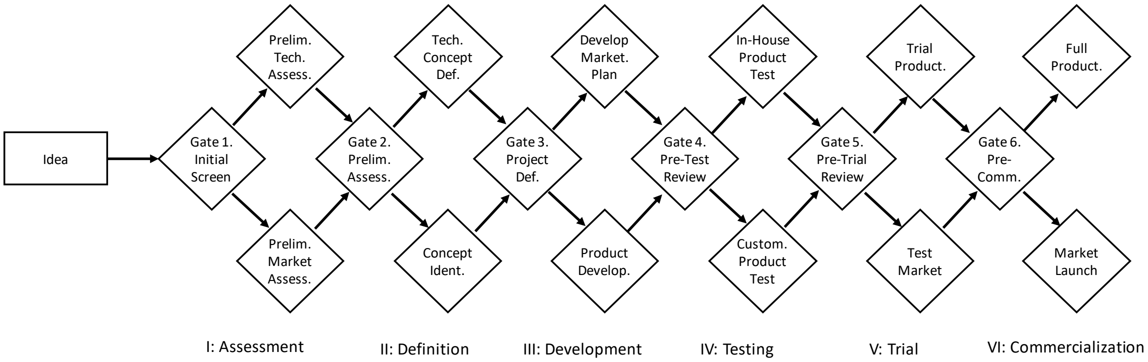

Figure 1. Cooper's Stage and Gate Process for NPD. Source: Cooper (1988).

The tools described within the methodology contained herein attempt to align neatly with the activities identified by Cooper as occurring in Stages 1-4. These Stages will be described in more detail in the following passages. Cooper's first Stage is "Assessment." This first Stage is inexpensive. This stage will determine the technical and marketplace merits of the product. This stage should include both a preliminary market assessment and preliminary technical appraisal (Cooper 1988, 251).

Stage 2 is titled "Definition." This is the final stage prior to product development. "Defining the product requirements and design" are key activities within this stage (Cooper 1988, 253). Market research activities, including "market research for product design", should be conducted during Stage 2, as should competitive analysis and concept testing (Cooper 1988, 253). The translation of "customer wishes into technically feasible product concepts" should also occur, as a function provided by technical staff. "Production feasibility is also an issue" during this stage (Cooper 1988, 253).

Cooper describes Stage 3, titled "Development," as the stage where product development work is undertaken (Cooper 1988, 253). Other activities that occur in Stage 3 relate to the development of a marketing plan. Product quality testing and user testing occur in Stage 4, titled "Testing." In-house testing and user/preference tests occur in this stage (Cooper 1988, 253).

The final two stages consist of trials for both production and markets, in Stage 5 "Trial" and Stage 6 "Commercialization" which works toward production and market launch (Cooper 1988, 254). Stage 5 will test for the production process and the economics of production, but Cooper notes that this stage may not be economically feasible for all NPD efforts, and therefore is a viable candidate for omission (Cooper 1988, 254). Additionally, Cooper's Stage-Gate Process provides the basis for Jagoda, Maheshwari, and Lonseth's methodology, which is described in more detail in the following section (Jagoda, Maheshwari, and Lonseth 2010, 367).

2. The Jagoda Model

As a follow on to Cooper's work, Jagoda, Maheshwari, and Lonseth applied the Stage-Gate process to technology transfer projects in support of a company acquiring new capabilities. As Kumar, et al. discusses in "State Sponsored Large Scale Technology Transfer Projects in a Developing Country Context"; developing countries can increase and improve technology development within their economy through the effective use of technology transfer mechanisms. It does this by aiding in the "diffusion process of newer technology from developed to developing countries" (Kumar et al. 2007, 630). In addition to this, in "Key Issues in Managing Technology Transfer Projects: Experiences from a Canadian SME," Jagoda, Maheshwari, and Lonseth (2010) point out that many small and medium sized companies are now using technology transfer mechanisms in innovative ways. These mechanisms can help them "quickly respond to changes in the competitive landscape", or they can provide key strategies in reducing their research and development costs (Jagoda, Maheshwari, and Lonseth 2010, 366–367).

However, even with all of the potential benefits, companies still struggle to initiate successful technology transfer programs. One reason private industry struggles with these innovations, as described by Grönlund and Frishammar, is the "challenge of sustaining internal commitment over a sufficient period of time to realize the benefits" (2010, 107). It is critical that clearly defined innovation practices, systems, roles, and responsibilities must be adapted, and reliance on ad-hoc processes must end, "in order to ensure a successful adoption of open innovation across the organization." Thus, "modifying existing innovation activities and processes to fit with innovation principles, rather than creating something completely new," is one challenge "in realizing the potential benefits of innovation" (Grönlund and Frishammar 2010, 107). This is also true for federal laboratories and their approach to innovative technology transfer opportunities as will be demonstrated throughout this thesis.

Jagoda, Maheshwari, and Lonseth's described method provides systematic approach to managing technology transfer projects by providing a spotlight on resources and constituent activities (2010, 367). Similar to Cooper's method, the Jagoda method provides an operational framework consisting of six stages and gates but applied toward technology transfer projects rather than new product development projects. Figure 2 describes the six stages and gates demonstrated by Jagoda, Maheshwari, and Lonseth (2010, 368) Although Jagoda, Maheshwari, and Lonseth's research was focused on technology transfer toward assimilating a new capability, this same process can be used for new product development.

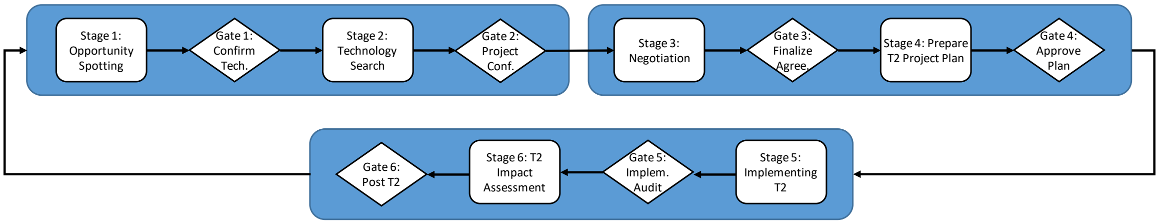

Figure 2. Jagoda, Maheshwari, and Lonseth's Stage and Gate Model for Technology Transfer. Source: Jagoda, Maheshwari, and Lonseth (2010).

Jagoda's model contains the following stages and gates: "Stage 1: Opportunity spotting and identifying value enhancing technologies"; "Gate 1: Confirming identified technologies"; "Stage 2: Focused technology search"; "Gate 2: Project confirmation"; "Stage 3: Negotiation"; "Gate 3: Finalizing and approving agreement"; "Stage 4: Preparing a TT project implementation plan"; "Gate 4: Approving implementation plan"; "Stage 5: Implementing TT"; "Gate 5: Implementation audit"; "Stage 6: TT impact assessment"; "Gate 6: Developing guidelines for post-TT activities" (Jagoda, Maheshwari, and Lonseth 2010, 368). These stages and gates are described more in depth below, but the methodology presented herein will align with Jagoda's Stages 1–5.

During Stage 1, market trends should be the critically evaluated by the project team. Shifts in customer preferences, and competitor technology trends, or any changes in government initiatives and regulations should also be identified and evaluated. These activities are carried out to identify potential technologies for technology transfer opportunities. The private industry partner developed technology roadmaps and carried out a preliminary market assessment (Jagoda, Maheshwari, and Lonseth 2010, 368).

In Stage 2, the project team prepared a detailed business case for the identified technologies. The tools used for this process can include “checklists, scoring models, and analytical hierarchy process (AHP)” (Jagoda, Maheshwari, and Lonseth 2010, 368). These activities may include “technology specifications, project financials, the project plan, and the business case” (Jagoda, Maheshwari, and Lonseth 2010, 368). The team established a clear set of specifications for the technology being considered and detailed how this technology is expected to enhance the industry partners competitiveness. The team also evaluated the extent to which the technology can be used and the gaps that will be bridged (Jagoda, Maheshwari, and Lonseth 2010, 369).

Stage 3 activities consist of initiating negotiations with the suppliers. The technology’s value is critical during negotiation. The transferor can rely on such things as ownership of a desired technology and reputation to increase its bargaining power. On the other side of the negotiating table, the transferee might use local market access, networks and knowledge to gain position. Additionally, low cost labor and raw materials may also be leveraged. During this Stage, activities such as reaching agreement amounts, preparing agreements, and establishing effective channels of communication are completed (Jagoda, Maheshwari, and Lonseth 2010, 369).

During Stage 4, the activities are aimed at ensuring a sound infrastructure and working “closely with the transferor to draft a preliminary TT implementation plan” (Jagoda, Maheshwari, and Lonseth 2010, 370). Also at this point, pragmatic training and education schedules should be under development for the workforce (Jagoda, Maheshwari, and Lonseth 2010, 370).

The last stage that the federal laboratory partner is likely to be involved in, and a major focus of this thesis, is Stage 5. Stage 5 activities include "identifying changes to be made to the product or process to suit local conditions." This stage is where the majority of additional information provided under the methodology described herein will have the biggest impact (Jagoda, Maheshwari, and Lonseth 2010, 370).

The Gates and Stage 6 are activities that are mostly internal to the private industry partner, and therefore not covered in depth within this thesis. Additional information regarding the two Stage-Gate processes can be found in "The New Product Process: A Decision Guide for Management" authored by Robert G. Cooper and "Key Issues in Managing Technology Transfer Projects: Experiences from a Canadian SME" written by Jagoda, Maheshwari, and Lonseth (Cooper 1988, 239–240) (Jagoda, Maheshwari, and Lonseth 2010, 366–367).

3. The Grönlund Model

In their article "Open Innovation and the Stage-Gate Process: A Revised Model for New Product Development," Grönlund, Sjödin and Frishammar (2010) state "Innovators Win." When companies seek to maximize returns from NPD, those companies can and should use both internal and external ideas, as well as internal and external paths to market. They cite Proctor & Gamble as an example of this.

> Procter & Gamble went from a "Research & Develop" strategy to a revised development strategy called "Connect & Develop." Connect & Develop aimed at profiting from the use of ideas from millions of external inventors worldwide, which ultimately allowed the company to increase R&D productivity by about 60%. (106)

Grönlund, Sjödin and Frishammar (2010) describe a methodology for open innovation that is based on the Stage-Gate process for organizing new product development. A dynamic, practitioner-oriented work model is presented by Grönlund, Sjödin and Frishammar, that leverages the benefits of open innovation. Their model allows systematic reconfiguration and evaluation of the way value is created and captured through new product development, while also minimizing the associated risks (Grönlund, and Frishammar 2010, 107). This is similar to the method described previously by Jagoda, Maheshwari, and Lonseth, providing a technology transfer methodology for use by small and medium business that is also modeled after Stage-Gate. The Grönlund methodology is depicted in Figure 3. The methodology is visually different from the previous two literature examples, but nonetheless, describes a Stage-Gate methodology.

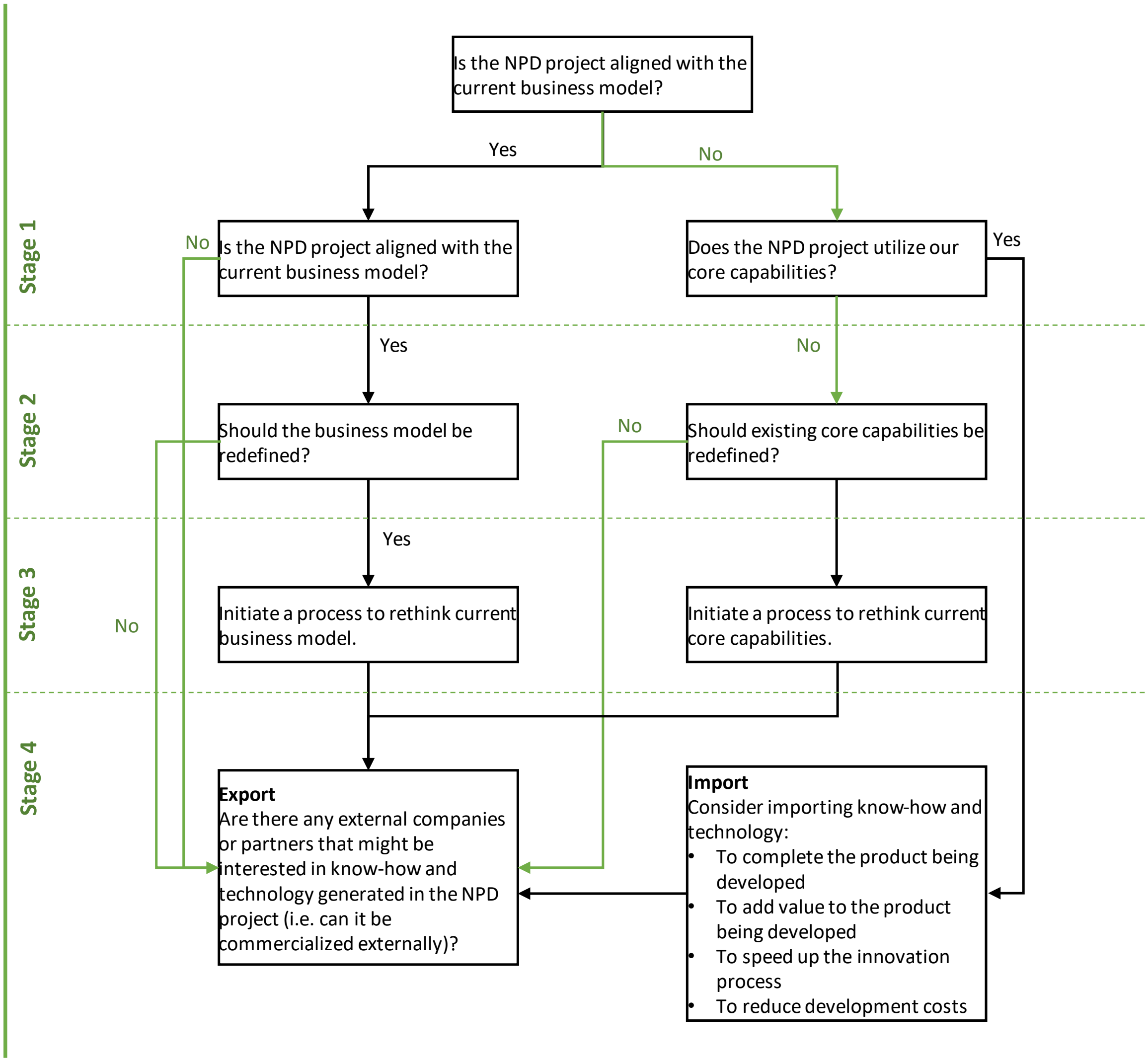

Figure 3. The Grönlund, Sjödin, and Frishammar Open Innovation Stage and Gate Model. Source: Grönlund, Sjödin, and Frishammar (2010).

Note that important "Gate" decisions in Grönlund's methodology focus on whether to "import" or "export" a new technology. The federal governmental parallel terminology for these activities are "Spin In" or "Spin Out." "Spin In" and "Spin Out" practices will be described in the later sections of this manuscript. However, since this thesis focuses on technology transfer efforts with businesses to reduce Defense Acquisition times, it is the expected that both the Jagoda and Grönlund methodologies will serve as models to which this effort aligns.

C. TECHNOLOGY TRANSFER APPLICATIONS

In 1990 Souder, Nashar, and Padmanabhan published "A Guide to the Best Technology-Transfer Processes." This paper drew from several references to describe "a systematic process, consisting of interacting roles and stages" of activity (Souder, Nasher, and Padmanabhan 1990, 5). Although similar, it is notable that this work does not mention Cooper's Stage-Gate work from the previous decade.

Souder, Nashar, and Padmanabhan describe four stages in technology transfer activities. They are

> 1. Prospecting (Stage I…)…research, analytical, and decisionmaking activities aimed at screening alternative concepts or technologies and selecting the ones that fit the users' requirements.
> 2. Developing (Stage II)…physical and laboratory R&D activities focused on enhancing, elaborating, embodying, and tailoring the selected technologies from Stage I to meet the users' requirements.
> 3. Trial …(Stage III), the developed technologies are field tested.
> 4. Adoption …(Stage IV)…final development, technology modification, and user implementation activities. (Souder, Nasher, and Padmanabhan 1990, 5-6)

A side-by-side comparison with Cooper's stages demonstrates a strong alignment between the New Product Process and Technology-Transfer Processes. This is strong evidence that technology transfer methods within the DoD and federal laboratory system can, and should, be aligned to the methods employed by industry partners for the development of new products.

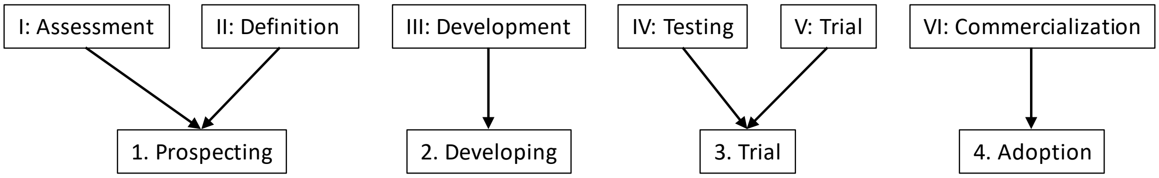

Figure 4. Alignment of Cooper's New Product Process to the Souder's Technology-Transfer Stages.

In 2018, Landree and Silberglitt published "Application of Logic Models to Facilitate DoD Laboratory Technology Transfer." Landree and Silberglitt suggested that technology transfer did not have a universally accepted definition of successful. They proposed a method to assist the DoD to "monitor and track technology transfer from laboratories to customers," and simultaneously assessing the success of these efforts (Landree and Silberglitt 2018, 1). Landree and Silberglitt proposed a model combining element of the logic-model framework, technology-transfer approach and the Navy R&D process to establish "a definition of successful technology transfer that may be applied across the Defense Laboratory Enterprise" (DLE) and provide guidance for assessing and monitoring the technology transfer (Landree and Silberglitt 2018, 1). The Landree and Silberglitt model provides a blueprint for how resources, activities and outputs lead to outcomes. Figure 5 provides a schematic of the logic model blueprint to technology transfer using the following elements; inputs refers to the resources and information, and activities represent what an organization does on daily basis. Outputs are the direct products, customers are the intended users, and outcomes are the changes that occur and the benefits that result from the use of an output. Finally, external factors defined as circumstances or events that are exogenous to the program and either positively or negatively affect an organization's ability to achieve outcomes. Additionally, the model traces the program across the operational cycle and integrates the Navy's R&D process (Landree and Silberglitt 2018, 7).

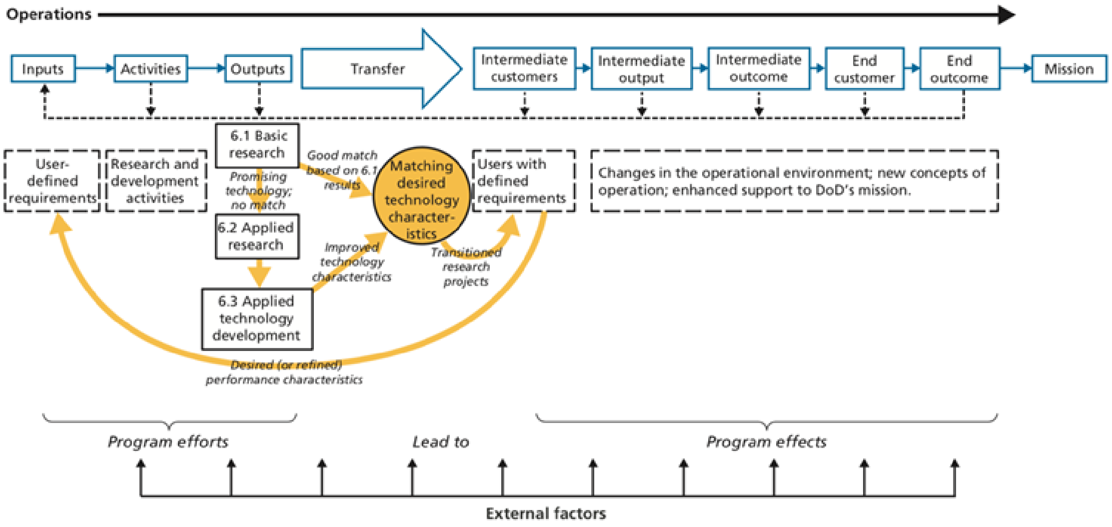

Figure 5. Schematic of Connection between Logic Model Elements and Technology Transfer. Source: Landree and Silberglitt (2018).

D. IMPROVED KNOWLEDGE SHARING

Although little open literature sources discuss knowledge sharing with federal laboratories, there is significant literature reference to the benefits of increased knowledge sharing between industry and academia. Furthermore, an increase in knowledge sharing has been demonstrated to increase innovation activities within the concerned parties. In his 2005 paper "Industrial R&D Laboratories: Windows on black boxes," Adams provided an "overview of the survey-based literature on industrial Research and Development (R&D) laboratories" in which he discussed private-public partnerships and research alliances (129). This study demonstrated "general information sharing among suppliers, manufacturers, and customers, including competitors" that leads to an increase in that firm's R&D activities (Adams 2005, 132). Additionally, as highlighted by Wilhelm et al. (2019) Adams demonstrates that firms experience a higher technical proficiency and an increased research output when they participate in geographical-proximity-based alliance. A university science park is a good example of a proximity-based alliance.

This was also supported by Woeter while studying the "technological orientation of firms and universities and their propensity to have knowledge and technology transfer" activities (2011, 828). Woeter's study described the productivity gains of market sectors with an interest overlap between academia and industry. Woeter noted that "great technology proximity between universities and private enterprises increases the probability of transfer activities" and that this is particularly true "in smaller firms (less than 500 employees or less than 300 employees)" (858).

This work was followed by Hess and Siegwart in 2013. The three case studies presented by Hess and Siegwart introduce and discuss R&D Ventures "as a practical phenomenon in the energy industry" (175). Their study indicates that the ventures can "improve the technology transfer for breakthrough innovation and future technologies" (175). Knowledge exchange is a primary factor in achieving these results.

Lastly, in the 2015 paper "Knowledge Effects on Competitiveness: from Firms to Regional Advantage," Caiazza, Richardson, and Audretsch also addressed equity joint ventures (2015). They note that "knowledge has the greatest potential to serve as source of sustainable advantage generating economic rents that enhance firms' position on their competitors" (900). Caiazza, Richardson, and Audretsch also demonstrate the benefits of "formal inter-organizational linkages, such as alliances or networks, aimed at facilitating knowledge sharing" (900). This knowledge, regardless of how it is generated, provides commercialization and entrepreneurship opportunities (Caiazza, Richardson, and Audretsch 2015).

E. MARKETING

In 1996, Cooper presented a study that followed "The New Product Process: A Decision Guide for Management," which described the three cornerstones to successful product development. This was titled "Overhauling the New Product Process." Both of these studies identify the importance of product design based on user needs and input (Cooper 1988; Cooper 1996). Wright, Vohora, and Lockett further support these points in the 2004 paper "The Formation of High-Tech University Spinouts: The Role of Joint Ventures and Venture Capital Investors" (Wright, Vohora, and Lockett 2004). According to Wright, Vohora, and Lockett; there is a need for a high level of understanding of market intelligence and user needs to support successful technology transfer activities.

In "Doing Technology Transfer in Federal Laboratories (Part 1)" Carr (1992a) describes two types of technology transfer. Technology-pull, the case in which private industry “pulls” a technology from a research laboratory into the commercial market, and technology-push, when a research laboratory promotes a technology for which a market exists. He singles out technology-pull as the more desirable; however, he also acknowledges that technology-push is the more common pathway. In addition, Carr notes a significant marketing effort is required to support “technology push” technology transfer efforts. In “Menu of Best Practices in Technology Transfer (Part 2),” which was published in 1992, Carr describes the “resource intensive and costly” technology-marketing process (26).

F. DISCUSSION

The use of logic models for tracking and monitoring technology transfer activities and success while connecting to the Navy R&D process mentioned earlier is useful. However, although this model has utility for the federal laboratories, it does not address how the warfighter generates requirements to be developed from a bottom up perspective, nor do they align with Carr’s case of “technology pull” (Carr 1992a). The model proposed by Landree and Silberglitt assumes a top-down approach with validation input from the warfighter (Landree and Silberglitt 2018, 6). In 2002, Marine Colonel Patrick Dulin posed the question, “Why can’t the U.S. Marine Corps warfighter simply and rapidly register an acquisition requirement and, in turn, receive a simple and rapid response that the requirement was either initiated or disapproved?” (Dulin 2002). To this hypothesis, Dulin concluded three root causes; lack of knowledge and confidence with Marine Corps requirements initiation procedures by warfighters, requirements initiation procedures codified in Marine Corps Order 3900.4D, published in 1991, created a process that was cumbersome, and increased demands on the warfighter drove a culture of short-term, band-aid remedies.

Although Dulin’s focus was the Marine Corps, the same arguments could be made for all services, particularly the Navy. Dulin proposed to address these issues, a simplified, standardized requirements initiation process must be adopted. Additionally, he concluded by using “a simple, rapid procedure for the warfighter” to nominate a requirement, the use of a standardized process would distill and focus “all warfighter requirements into a coherent, synchronized warfighting roadmap for the future” (53). The warfighter is not an expert in requirements generation, however, is an expert in the needs of the warfighter. A successful technology transfer model should include a streamlined and standard process for the warfighter to nominate a requirement for development without having to be an expert in the DoD acquisition and product development process. The T2 methodology should then align potential commercial needs with the requirements of the warfighter, for potential dual-use technology opportunities, followed by methods for rapid development to demonstration. This process starts with improved knowledge sharing across the DLE and with the warfighter, and a better understanding of, and alignment to, the needs of the warfighter.

III. SYSTEM ARCHITECTURE PRACTICES TO FACILITATE DEPARTMENT OF DEFENSE TECHNOLOGY TRANSFER

This chapter was previously published *The Journal of Technology Transfer,* and is reprinted here with permission from the authors. Reprinted by permission from Springer Nature Customer Service Centre GmbH: Springer Nature *The Journal of Technology Transfer* System architecture practices to facilitate Department of Defense technology transfer, Christopher Wilhelm, Erin Thompson, Kristin Giammarco et al, COPYRIGHT (2019) https://link.springer.com/journal/10961

A. INTRODUCTION

It has clearly been a trend over the past several decades that technology advancement occurs at a greater pace in the private sector than in the federal laboratory system. This is, of course, not true of all technologies but has certainly been demonstrated in several sectors. Private industry's ability to more dynamically refocus, rapidly acquire starting materials, and their increased flexibility in addressing requirements provides them with a platform that better allows for the iterative prototyping and design capability needed to rapidly advance the TRL of systems.

B. RATIONALE FOR THIS WORK

The benefits of increased and improved knowledge sharing to support innovation activities are well documented within the literature. Most of this body of work, however, focuses upon the private sector and academia. In 2005, Adams provided an overview on industrial Research and Development (R&D) laboratories in which he discusses research alliances and private-public partnerships. Adams' study indicated that a firm's R&D often originates from outside that firm, and he describes that it is knowledge sharing between manufacturers, suppliers, customers, and competitors that leads to this phenomenon. Additionally, Adams demonstrates that firms located inside a university science park, where knowledge sharing can be considered geographical-proximity-based, demonstrate a higher technical proficiency and an increased research output (Adams 2005).

In 2011, Woeter added to this concept by studying the potential for knowledge and technology transfer activity as it relates to technology proximity. Woeter's study described the productivity increases realized in certain market sectors where there was an interest overlap with both academia and industry. Interestingly, he also noted an increase in the use of academic research by smaller firms defined as firms with less than 500 employees, and firms with less than 300 employees (Woeter 2011).

These studies, as well as others, are supportive of the work described by Hess and Siegwart in 2013. Hess and Siegwart present a multiple case study on the use of R&D Ventures to bridge the gap between academic discovery of breakthrough technologies and established companies. In all three cases presented, the establishment and use of an R&D Venture demonstrated improvement when compared to similar, internal R&D projects carried out by established companies. It is important to note, however, that while Hess and Siegwart propose that an R&D Venture can serve as an opportunity for technology transfer and R&D cooperation between industry and academia, they describe knowledge exchange as one of the primary factors vital for success (Hess and Siegwart 2013).

Caiazza, Richardson, and Audretsch also addressed equity joint ventures in 2015, in Knowledge effects on competitiveness: from firms to regional advantage. Caiazza, Richardson, and Audretsch note the benefits of knowledge sharing and interactive learning through formal inter-organizational linkages; and that knowledge, as a resource, has the greatest potential to serve as a firm's source of sustainable advantage. Knowledge; whether created internally, acquired through alliances, or generated by knowledge spillover, provides an opportunity for commercialization and entrepreneurship (Caiazza, Richardson, and Audretsch 2015).

C. SYSTEMS ARCHITECTURE

Considering the many documented benefits of increased knowledge transfer in support of innovation activities, it is reasonable to look for ways to improve knowledge sharing that already exist in close proximity to the TTO. However, while the federal laboratory system employs many systems engineers and systems architects, there is very little written precedence for the application of systems engineering and systems architecture tools and techniques as applied toward the mission of technology transfer. This body of work provides a rationale for TTOs to work more closely with the systems architects already on staff in federal laboratories, as a means of improving knowledge sharing.

Crawley, Cameron, and Selva ask two simple questions when they introduce new readers to systems architecture: Does the system meet stakeholder needs and deliver value? Does the system integrate easily, evolve flexibly, and operate simply and reliably? These are the same questions that should be asked when a government technology is being considered for transfer into the private sector for commercialization. However, in light of the above discussion, one can reasonably assert that it is the responsibility of the TTO to provide this information to a commercialization partner as part of the knowledge transfer process, without being explicitly asked for it. The common systems architectural tools of decomposition, partitioning, mapping, and allocating function-to-form can answer these questions using informative graphical representations. The models can be readily produced by including a systems architect in early stage technology transfer activities and can be provided to commercialization partners to speed further development and reduce risk.

SEBoK states that "developing a candidate physical architecture model for a system consists of first identifying the system elements that can perform functions of the logical architecture model" (2019). A "discrete part of a system" can be referred to as a system element, and a complex system can be composed several hundreds of elements. (SEBoK contributors 2019) These elements can consist of, but is not limited to, hardware, software, data, humans, or processes, and can be structured in layers of systems and system elements. System elements are bound to each other by an interface (SEBoK contributors 2019). Architectures can be described using two fundamental structures, one based on function and the other on form. The function architecture defines what the system does. The form architecture defines how the system does it. The form architecture model elements are allocated element-by-element from the function architecture model. The form architecture is eventually built from these system elements and interfaces, including interfaces with external elements. These form architecture elements and interfaces can be related to design properties. If the form "element complies with a requirement, the design property will relate to (or may equal) the requirement" (SEBoK contributors 2019).

Partitioning and allocation are useful in the decomposition, gathering, or separation of functions for the purpose of identifying the system elements that support these functions. In this manner, system architects deduce "design properties to properly equip their physical architecture" models to provide the capabilities needed to meet stakeholder requirements (SEBoK contributors 2019). Some of the major activities carried out include: searching for system elements able to perform functions, ensuring these "system elements exist or can be engineered", and assessing these system elements and their design properties (SEBoK contributors 2019).

The architecture models presented here were produced using Innoslate version 3.9. Innoslate is a Product Lifecycle Management tool that combines standard SysML, LML, and Requirements View with Monte Carlo and Discrete Event simulators. It is capable of integrating requirements analysis, functional analysis and functional allocation; and sufficiently served to model the two relatively simple systems introduced in the next section. It is worth noting the simplicity of the models provided. The visual nature of these models allows for easy access to the information provided by the architectural decomposition exercise. In a means similar to the modern graphical user interface (GUI), the systems architecture model is able to provide several strings of useful information in a simple visual model.

This "ease of access" to architectural design and function provides access to important information for potential partners to apply toward architectural redesign or if a change in functionality is required. The use of spider diagrams was chosen based on the work of Maier and Rechtin. They advise that the choice of the integrated model should be based on three criteria (Maier and Rechtin 2009, 286): Does the model span three or more baseline visions? Does the modeling language have enough formality to support intraview and interview consistency checking views? Can the model be used from concept presentation to transition to disciplinary engineering? Again, these questions become essential for increased knowledge sharing during technology transfer activities. Rephrased they might be:

- Does the model provide sufficient information to the commercial partner?
- Does the model use language that is understandable to the commercial partner?
- Can the model be used effectively throughout a new product development lifecycle?

Spider diagrams address the baseline visions of “Behavioral or Functional” view by use of the functional hierarchy chart, and the “Form” view by use of the physical decomposition. The “Purpose/Objectives” view is addressed by the marrying of the functional hierarchy chart with the physical decomposition to respond to the client’s needs (Maier and Rechtin 2009, 225). Easy access to this information allows for the practice of systems architecture to alter and adjust the system elements to meet the needs of the technology transfer partner.

It is important for the federal laboratory to ensure that these models use simple, descriptive language to ensure that the model is easily understandable by a variety of potential commercial partners across multiple commercial markets. This facilitates the transfer of knowledge, and therefore, the use of federally “specific” verbiage or acronyms is discouraged. Lastly, the model needs to be designed in such a way as to provide usefulness across the product development lifecycle. Systems elements should be decomposed in a systematic way. The elements become more concrete and less abstract in their representation as uncertainties are resolved and system definition matures. Likewise, the use of design heuristics (Maier and Rechtin 2009, 250) should reduce as the system becomes more mature and well-defined as the product development proceeds. This is demonstrated in the following section. As the functional architecture develops through work within the technology transfer partnership, the form architecture evolves to meet the functional requirements.

The following sections of this thesis will describe two Navy-developed technologies that have been decomposed for the purpose of identifying system elements and the system functions that each element supports. These work products can provide an industry partner additional, useful information regarding the specific system elements that can be altered to provide alternate/additional capabilities to the end user. This information can be used by the industry partner to identify alternate materials or configurations that will provide for additional, or even improved functionality from these technologies. Due to budgetary and mission constraints, DoD laboratories would have difficulty in justifying these changes, but a private partner can make these changes easily and more rapidly advance the underlying technologies or alter them to meet differing market needs and requirements, all along, working to advance the government owned technology providing additional capabilities to the U.S. Warfighter in the future.

D. FEDERAL LABORATORY CASE STUDIES

Two case studies are presented here to demonstrate the use of systems architecture to support increase knowledge sharing during technology transfer activities. These examples are the “Modular Charge System” and “Blast Mitigation Barrel”, developed at Naval Surface Warfare Center Indian Head Explosive Ordnance Disposal Technology Division.

1. Case Study: Modular Charge System

The modular charge system was developed and patented by Naval Surface Warfare Center Indian Head Explosive Ordnance Disposal Technology Division (NSWC IHEODTD) to address size, weight, and power (SWaP) concerns being realized by the explosive ordnance disposal (EOD) warfighter due to an increase in dismounted operations. The underlying concept was to provide a multi-mission, configurable, hand-packable energetic tool that was lightweight and required a small footprint. The patent for this tool was issued on 07 July 2015 and is described in U.S. Patent Number 9,074,855 (U.S. Patent No. 9,074,855, 2015). It is made up of five physical attributes; the Cap Well, Wave Shaper, Modular Walls, Rail System, and Shaped Charge Liner. The Cap Well can be used with or without a cap adaptor, and three copper shaped charge liners can be incorporated including a conical liner, linear liner, and flyer plate (U.S. Patent No. 9,074,855, 2015). The authors are unaware of any similar technologies that have been reduced to practice. An operational schematic of the Modular Charge System is shown in Figure 6. It depicts the modular walls in their collapsed state (I), the assembly of the system

(II), the conical/flyer plate configuration (III), the linear configuration (IV), and the extended linear configuration (V).

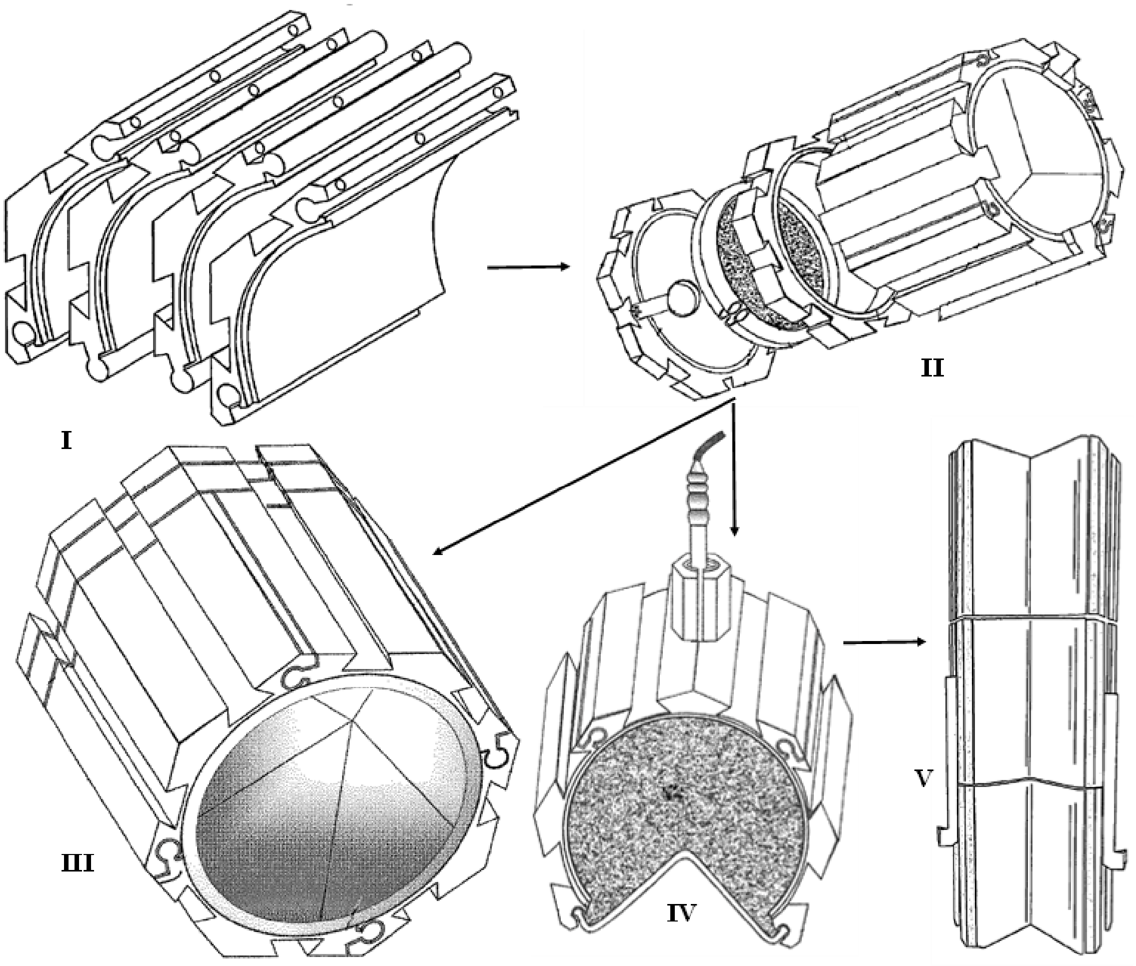

Figure 6. Operational Schematic of Modular Charge System Depicting Multiple Configurations.

A physical decomposition of the tool is provided in Figure 7. There is no documented requirement for the Modular Charge System, but the loosely defined needs of this tool were to provide for an improved SWaP and smaller footprint with no decrease in capability. These capabilities included: multiple means of priming the energetic fill and multiple means of interacting with the target. The concept was to provide several tools in a single, re-configurable package to address these needs. Furthermore, by using a lighter weight polymer construction, the weight would be additionally improved. A functional decomposition of the Modular Charge System can be found in Figure 8.

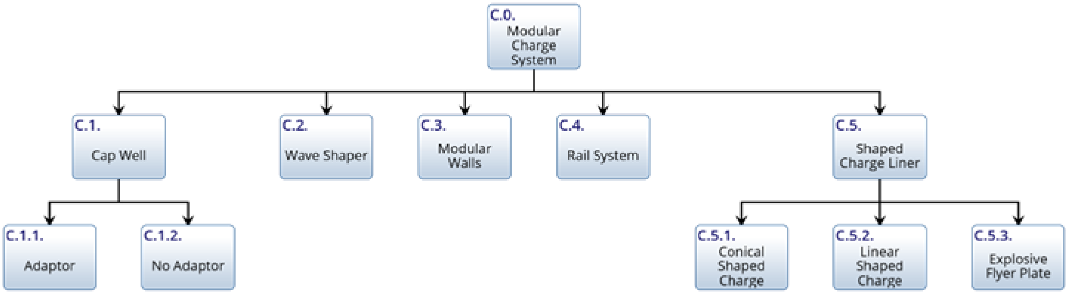

Figure 7. Physical Decomposition of Modular Charge System.

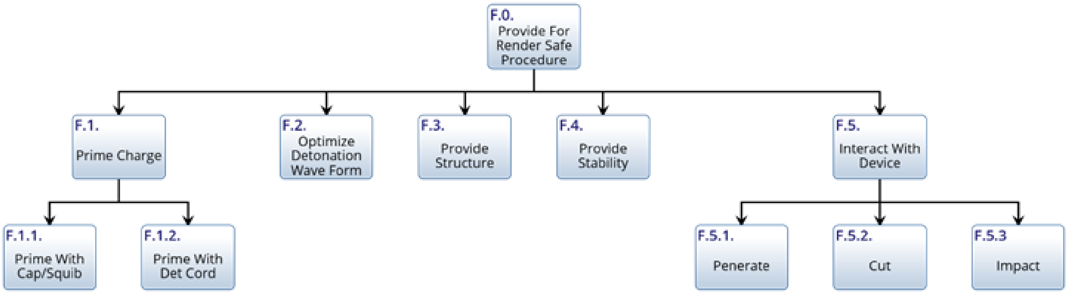

Figure 8. Functional Hierarchy Chart of Modular Charge System.

Decomposition allows for a mapping of physical architecture to functional architecture. This model is demonstrated in Figure 9, a spider diagram of the Modular Charge System. This model provides an easy to understand, graphical representation of each system element, how those system elements come together, and the functional capabilities that those system elements support in the overall architecture. If the commercial partner fully understands the needs of the customer from the on-set, this will provide an excellent starting place for redesign. If the needs of the potential market are not fully understood, the spider diagram provides a roadmap for the commercial partner to follow for redesign, or possible upgrade.

For example, Figure 9 demonstrates that the conical shaped charge liner, linear shaped charge liner, or explosive flyer plate are the three system elements that interact with the target device. Therefore, if the commercial partner requires a different kind of interaction with the target device, these three system elements should be the starting point for redesign. In this way, as the market's needs evolve, the system's architecture also evolves to meet these needs.

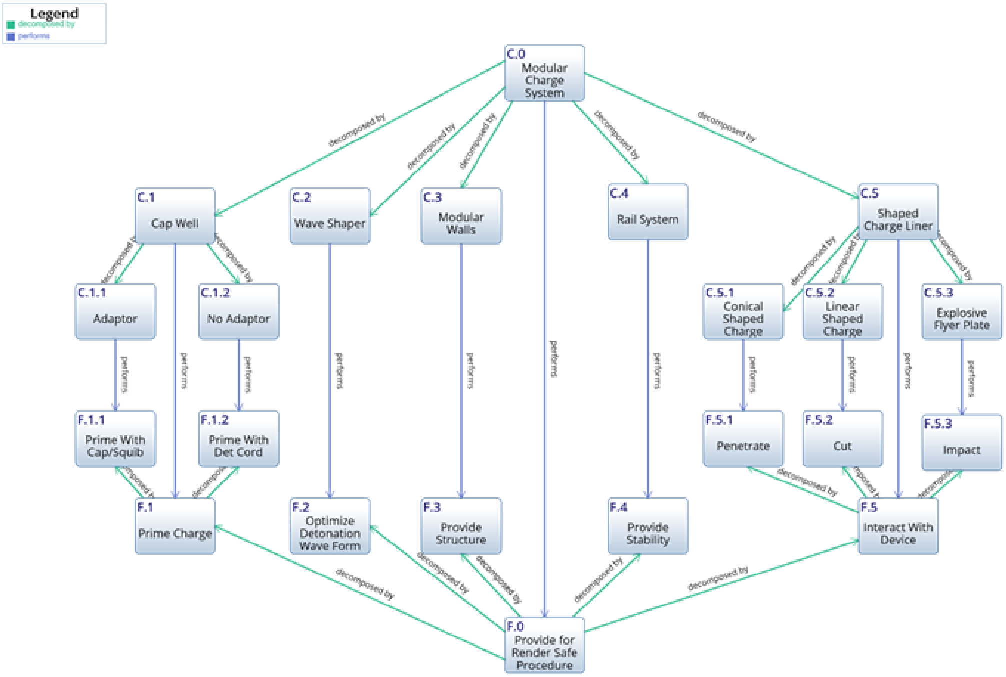

Figure 9. Spider Diagram of the Modular Charge System Mapping Physical Assets to Functional Capabilities.

2. Case Study: Blast Mitigation Barrel

The blast mitigation barrel was developed in a collaborative effort by NSWC IHEODTD; the Massachusetts State Police (MSP); New York City Police Department (NYPD); New Jersey State Police (NJSP); Federal Bureau of Investigation (FBI); and the Bureau of Alcohol, Tobacco, Firearms, and Explosives as a result of a case study of the 2013 Boston Marathon bombing incident (U.S. Patent Application 104,462, 2018). The underlying concept was to provide a device that could mitigate the blast from a small improvised explosive device (IED), could be easily deployed and re-deployed, and needed a minimal footprint while in storage. A patent application was filed on 23 March 2018 and is currently in patent pending status (U.S. Patent Application 104,462, 2018). Although the authors are aware of similar devices being produced, none of these devices meets the readily deployed/re-deployed or minimal storage footprint requirements.

The blast mitigation barrel is made up of six physical assets; the Barrel (Trash Can), Barrel Liner, Boot, Inner Liner, Lid, and Filler. The Inner Liner can be made of a variety of solid materials and the Filler can be any of several available liquids or multi-component solutions (U.S. Patent Application 104,462, 2018). Figure 10 depicts an operational schematic of the blast mitigation barrel, showing it in its storage and assembled configurations (I), deployed configuration (II), when a threat is introduced (III), and when a threat is mitigated using the barrel (IV).

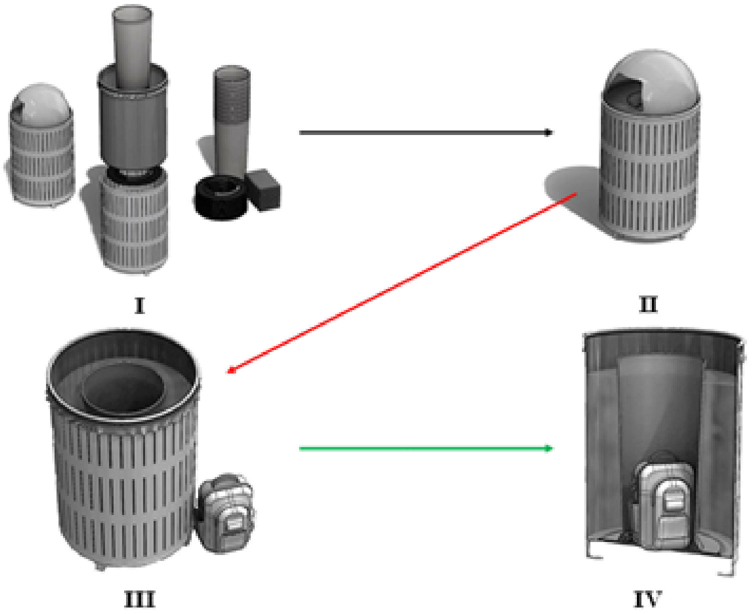

Figure 10. Operational Schematic of the Blast Mitigation Barrel Depicting Assembly and Threat Interaction.

A physical decomposition of the blast mitigation barrel is provided in Figure 11. As was the case with the Modular Charge System, there is no documented DoD requirement for the Blast Mitigation Barrel but a set of loosely defined needs for this device were described in a collaborative session of the inventors held on 02 August 2016. These capabilities included: mitigate blast event by funneling energetic release in a safe direction, break-up fragmentation produced by blast event, decelerate fragments produced by blast event, provide for easy deployment and re-deployment, and provide for easy storage when not in use.

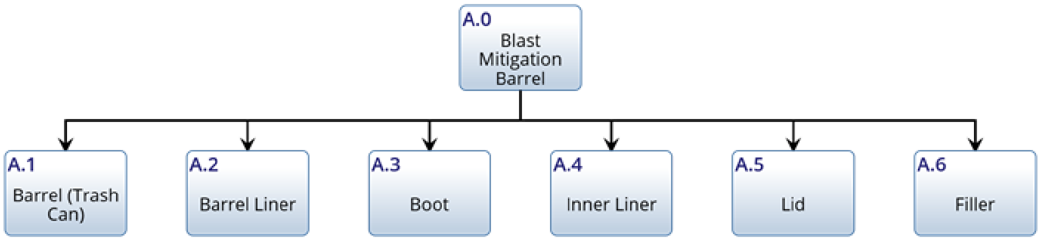

Figure 11. Physical Decomposition of the Blast Mitigation Barrel.

The concept consists of a fill-able and drain-able barrel that is capable of directing the energy released during a detonation event in an up-ward direction while working to mitigate the hazards of any resulting fragmentation. Furthermore, by using a commercially available trash can or city-provided trash receptacle, the device is non-obvious to criminals and citizens; therefore, working to improve security, decrease panic, and aid in crowd control. A functional hierarchy chart of the Blast Mitigation Barrel can be found in Figure 12.

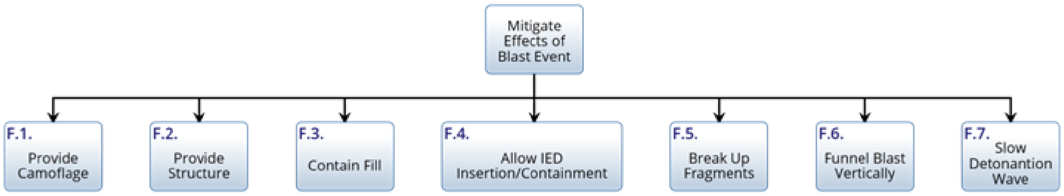

Figure 12. Functional Hierarchy Chart of the Blast Mitigation Barrel.

Once again, it is useful to view a form-to-function mapping in the form of a spider diagram for the Blast Mitigation Barrel (see Figure 13). Again, this snap-shot of physical and functional architecture identifies, for the commercial partner, appropriate system elements for further technology development or refinement that can lead to improvements in the effectiveness of the Blast Mitigation Barrel against proposed IED threats as the user's needs evolve. In the case of the Blast Mitigation Barrel, the spider diagram clearly indicates that the major elements interacting with the blast event are the Inner Liner and Filler. As the threat devices used in a specific area of operations evolve and mature, these are the first system elements that should be investigated for increased effectiveness. Again, the use of simple systems architecture models are effective means of reducing the waste of resources in addressing the evolution of the user's requirements, using decomposition and mapping to improve the research and development efforts of commercial partners.

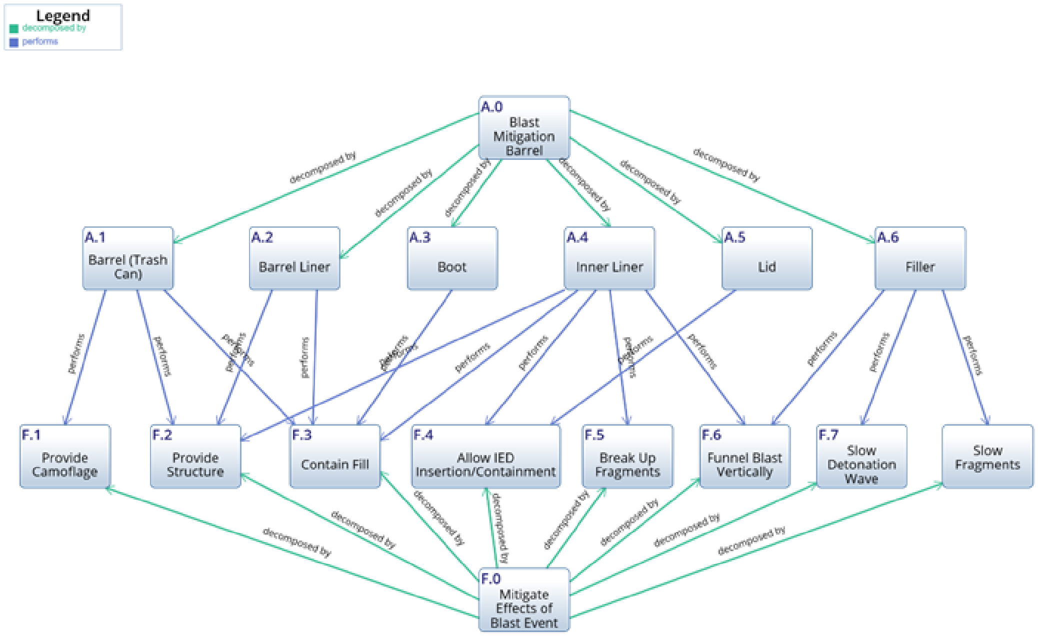

Figure 13. Spider Diagram of the Blast Mitigation Barrel Mapping Physical Assets to Functional Capabilities.

As an addition, in the Blast Mitigation Barrel effort, the logistics for deployment, re-deployment and storage are a strong secondary interest to the user. Therefore, a logistical decomposition could also be provided to the commercial partner, as a means of addressing these secondary user needs. Figure 14 displays the decomposed requirements identified within this logistical space. The design which allows disassembly of the Blast Mitigation Barrel was implemented to meet these portability and storage requirements. The components of the Blast Mitigation Barrel are designed to be inter-stackable to minimize the storage footprint, while the concept of a drainable filler allows for light weight during transportation.

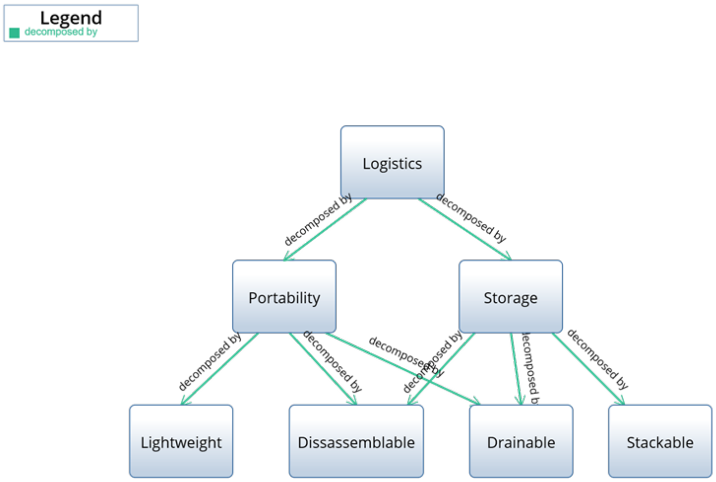

Figure 14. Logistical Decomposition of the Blast Mitigation Barrel.

The examples provided above are not exhaustive of the systems architecture tools and techniques that can be employed to increase knowledge sharing with commercial partners, and work to reduce their realized risk. The use of the systems architecture models, when properly employed, can provide a potential commercial partner with easy access to a large amount of additional information. In the above examples, the focus has centered on system element and system function, in large part because these can the easiest examples to understand. However, the spider diagram provides a large amount of information, which can also include the system interfaces (both internal and external) and performance objectives or requirements. These tools should be tailored and refined for specific technology transfer efforts to increase their effectiveness.

E. DISCUSSION

As Choudhry and Ponzio recognize, there has been an increased emphasis for federal Technology Transfer Offices (TTOs) to improve in efficiency and effectiveness in recent years (Choudhry and Ponzio 2019). Improved knowledge sharing is one means of achieving this goal. The use of common systems architecture practices, already widely employed within the federal laboratory system, can facilitate a higher level of knowledge sharing, in an easy to understand graphical format. If systems architects, and system architecture methods, are included early on in technology transfer efforts, the Technology

Transfer Offices within federal laboratories can readily provide this information to partners as part of the technology transfer package. Choudhry and Ponzio define the Transfer Rate metric as the number of new patent licenses granted divided by the total number of patent applications filed and identify this metric with the efficiency of laboratory TTO (Choudhry and Ponzio 2019). In essence looking toward the costs associated with filing new patents compared to the ROI from patent licenses. By providing partners with more easily accessible information regarding component advancements/alterations and lowering the realized risk toward providing additional or altered capabilities, technology transfer partners can more readily fill the needs of the private market sector. This practice can further be expected to increase technology transfer efforts with small businesses or start-ups, as small companies are likely to lack an internal capability, or staff numbers, to achieve this affordably. Access to increased knowledge upfront will ease the burden on federal laboratory technology transfer partners, provide additional information early on in the decision-making process, and lead to a higher number of more effective license agreements.

In the case of the Modular Charge System, a civilian public safety bomb squad may have a requirement to interact with a target in a different manner. For instance, penetration or cutting may not be the ideal type of target interaction for a possible IED staged in the middle of Times Square. The spider diagram indicates to the commercial partner that the Shaped Charge Liner is the appropriate physical component to alter or adapt to achieve this new capability. Although this effort may not align with a DoD requirement or need, as Joint Service Explosive Ordnance Disposal operates within a different envelope than civilian public safety bomb squads, and therefore should not be pursued using DoD funds, an industry partner will be working toward a different set of user needs. If the industry partner can increase commercial sales numbers through a small investment of internal development funds, it may be worth pursuing an alternate design. The knowledge provided through the examples in the previous section can help a commercial partner better leverage investment dollar to realize a more successful product. DoD System Architecture practices, such as the examples provided, can readily provide these touch points to industry partners for a more rapid and focused development effort, and therefore reduce the risk realized to meet market needs.

Similarly, in the case of the Blast Mitigation Barrel, threats to public safety are constantly evolving in response to the first responder technologies deployed to defeat these threats. The use of functional mapping provides industry partners with starting points to advance the technologies needed to defeat these evolving threats and provide for improved protection of the public. System architecture tools and practices will decompose the system with the purpose to indicate the proper system elements for advancement. An improved Inner Liner should increase the amount of fragment break-up, as new fragmentation patterns are employed, and thereby allow for better survivability of civilians in the immediate area of a detonation event. However, a more viscous filler might achieve this same effect while also serving to better mitigate the detonation pressure. The knowledge of these elements and how they function to support the capabilities of the over-all system allow for commercial partners to invest in the most useful improvements first.

F. CONCLUSION

There are many reasons that DoD programs pursue particular and specific system capabilities, good stewardship of tax dollars and increased transition success among them. However, these requirements do not always entirely overlap with the needs and requirements of commercial markets. Additionally, although the mission of technology transfer is to move government developed technologies to the private sector, most research and development programs cannot branch out to explore those needs expressed within the private sector unnecessarily. However, the tools that system architecture provides to federal laboratories can be utilized to significantly increase the understanding of technologies developed by DoD scientists and engineers for commercialization partners. Often, physical and logistical decompositions, functional hierarchies, and physical-functional mapping diagrams are developed and recorded routinely during early stage research efforts. But it is worthy to note that these tools not only help to focus DoD research and development efforts but can also be made available for turn over to private industry partners during technology transfer activities. Here, the authors provide an argument for the use of systems architecture tools as a means of increasing knowledge sharing and as means of providing simple graphical representations of how system elements support the over-all system function and capabilities. This will provide a roadmap for commercial partners to invest in technology improvement that will meet the needs of a non-DoD market. Inclusion of system architecture models, as demonstrated in the above examples, will also provide industry a means to evolve DoD technologies as user and market needs evolve into the future.

Although the tools described herein do not address a commercial partner's need to understand and respond to a given market sector's needs, this use of systems architecture does provide a means to improve knowledge sharing during technology transfer activities, increase the ROI of private industry internal research and development (IRAD) funds, and speed the advancement of capability improvements to meet those needs, once they are understood. Additionally, these advancements may be brought back "inside" the DoD if, and when, they become necessary within the military-specific operational envelope. This approach, when properly leveraged, can be expected to realize an increased speed of acquisition and has the potential to save costs as well.

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IV. MODEL-BASED SYSTEMS ENGINEERING (MBSE) TO SUPPORT TECHNOLOGY TRANSFER AND TECHNOLOGY

A. INTRODUCTION

Since 1980, the federal government has established a continuing series of laws to support and facilitate technology transfer (T2) within the federal laboratory system. The Federal Laboratory Consortium's "Green Book" provides a useful description of these legislative actions (Federal Laboratory Consortium for Technology Transfer 2013). In more recent years, technology transfer activities in the federal laboratory system have seen increased attention from the recent presidential administrations, with a focus on increasing the ROI of tax-payer dollars and improving the efficiency of Technology Transfer Offices (TTOs) (Obama 2011; Trump 2017; Trump 2018). However, the desire for better ROI, effectiveness and efficiency is not new, and in fact dates back several decades (Carr 1992a). This renewed focus has led to recent discussions of better metrics (Choudhry and Ponzio 2019) and a desire for improved tactics, techniques and procedures (TTPs) to both better track and better support federal TTOs. Activities that have been encouraged by both the Obama and Trump presidential administrations. It is worthy to note however, that although these improvements are greatly desired, federal laboratory TTOs must still meet today's budgetary constraints.

The U.S. Federal Technology Transfer Act of 1986 (Public Law 99-502, 20 OT 1986, as amended), or Title 15 U.S. Code, Section 3710, allows for federal laboratories to enter into cooperative research and development agreements (CRADAs) (Federal Technology Transfer Act of 1986). CRADAs allow for the creation of government-industry collaborations that can work toward commercializing technologies conceived within the federal laboratory, while lowering the cost (Bernard 2014). These agreements are commonly used by federal laboratories to facilitate technology transfer activities. To enhance these collaborative efforts, the concept of using simple Systems Architecture models in support of technology transfer activities was recently published by Wilhelm, et al. (Wilhelm et al. 2019). Systems Architecture models were described as an inexpensive means of enhancing knowledge transfer that is readily available to most federal TTOs

(Wilhelm et al. 2019). The use of tools and techniques already practiced within federal laboratories provides an inexpensive means of improving technology transfer activities and addressing the Choudhry and Ponzio metric of Transfer Rate (Choudhry and Ponzio 2019). However, successful technology transfer should not be limited solely to the number of patent license agreements (PLAs) established but should also be considered by the success of product launches.

To this end, this paper will describe the use of MBSE tools defined in the Department of Defense Architecture Framework (DoDAF) Version 2.02 as a means of enhancing a commercialization partner's understanding of the technology, its potential uses and the relevant market space that a federally developed technology can address. Similar to the previously described models (Wilhelm 2019), these tools are routinely practiced within DoD laboratories, and their development is well understood to many members of the DoD scientific and engineering community. These models can be developed efficiently, in a relatively short amount of time, and are low cost; therefore supporting the intent of increasing ROI metrics. However, they can prove extremely effective in providing an increased understanding to potential commercialization partners regarding potential markets.

MBSE is an appropriate method for communicating across multiple different stakeholders. As Piaszczyk (2011) describes, while each stakeholder has a different view of the system, MBSE brings a system model to the center stage for all the stakeholders to use together. Piaszczyk goes on to explain, that by making the model the focal point of the systems engineering effort, the requirements can be better understood, and the model refined in a shorter time. This is a large advantage over document centric requirements, making MBSE an attractive tool for technology transfer efforts (Piaszczyk 2011).

B. LITERATURE

As the following section will describe, TTOs often suffer in their ability to market technologies. However, although there are very few literature examples of systems engineering techniques supporting technology transfer activities, there are several examples of MBSE supporting technology marketing. This highlights an opportunity to use MBSE models and viewpoints in support of the technology marketing needs of federal TTOs. The following sections describe some of the literature precedence.

1. Technology Transfer and Technology Marketing

The Stevenson-Wydler Act of 1980 was intended as a "comprehensive national policy" meant "to promote United States technological innovation for the achievement of national economic, environmental, and social goals, and for other purposes" (Stevenson-Wydler Technology Innovation Act 1980). It was the first in a series of laws that support the T2 activities that now occur regularly within the federal laboratory system. The purpose of this act is "to stimulate improved utilization of federally funded technology developments" by "State and local governments and the private sector". These technology developments include inventions, software, and training technologies (Stevenson-Wydler Technology Innovation Act 1980). This act also specifies that each federal laboratory that employs 200 or more full time equivalent scientific, engineering or technical positions shall establish an ORTA to facilitate T2 activities. Additionally, the act states, "It is the continuing responsibility of the federal government to ensure the full use of the results of the Nation's Federal investment in research and development" (Stevenson-Wydler Technology Innovation Act 1980).

The Stevenson-Wydler Act was followed by a second piece of major legislation, known as the Federal Technology Transfer Act of 1986 (Federal Technology Transfer Act of 1986). As stated earlier, this act established the use of CRADAs as means for federal laboratories to perform collaborative research with other federal agencies, units of State or local governments, industry, public and private foundations, non-profits (including universities), or other persons; as well as allowing for the negotiation of Government-owned inventions or inventions that had been assigned to the Government. Additionally, this act states that "Technology transfer, consistent with mission responsibilities, is a responsibility of each laboratory science and engineering professional" (Federal Technology Transfer Act of 1986). In summary, the legislation enacted thus far makes it the responsibility of every federally funded scientist and engineer, ORTA, and federal laboratory to make the technologies developed using government funding available for commercialization when that technology can provide a benefit to the taxpayers, small businesses, and overall economy.

Ironically, in Robert Carr's "Doing Technology Transfer in Federal Laboratories (Part 1)" his response to the question "Why should a federal laboratory worry about how to do technology transfer better?" is not based on legislation. Instead, Carr focuses on the economy and U.S. competitiveness in global markets (Carr 1992a). Carr argues that the benefits of effective T2 activities include a better ROI in the investments made in the federal laboratory system, and the introduction of new technologies to improve productivity, the nation's effectiveness, and the standard of living (Carr 1992a). Whatever the motivation, it clear that the Government invests a large amount of monies in research and development, and the fruits of that research can benefit the private sector if they can be effectively and efficiently transferred for commercialization.

However, due to budgets and staffing, and the prioritization of patent filing over patent licensing, Technology Transfer Offices often focus less resources on the marketing of their technologies (Swamidass and Vulasa 2009; Closs 2012; Siegel 2004). As Swamidass discusses, high-tech inventions can be difficult to market in the first place, due to the lack of a ready market. Therefore, the TTO may need to investigate niche markets, new market creation, and valuate market space; followed by translating this into a business plan that is attractive and understandable by investors (Swamidass and Vulasa 2009). Many TTO staffs do not have the necessary skills and backgrounds to do this effectively (Swamidass and Vulasa 2009).

Closs et al. confirms this in 2012 when they describe an interview in which a researcher stated "the TTO does the paperwork, we do the development. Then we need to sell it." (Closs 2012) However, as Siegal et al. report, a major concern with TTOs is an inability to effectively market the patented technologies. However, in order to effectively achieve successful marketing, the TTOs need an understanding of the technology and the potential markets (Siegel 2004). The TTO need also be able to work with the commercialization partner to accurately assess the technologies worth, and evaluate the potential market space (Closs 2012; Siegel 2004).

Peter Drucker famously wrote “any business enterprise has two-and only these two-basic functions: marketing and innovation” (Drucker 1955). However, in the case of innovative technologies, or technologies that are not tied to a familiar customer paradigm, traditional market research is generally unhelpful in the marketing effort (Leonard and Rayport 1997). This is because, when a new technology is introduced, customers have no foundation upon which to formulate an opinion (Leonard and Rayport 1997). Furthermore, industrial organizations can often feel threatened by change and perceive new technology adoption as risky (Lewin and Bello 1997). One means to overcome this is by increasing communication between marketing and engineering (Fisher, Maltz and Jaworski 1997). Fisher, Maltz, and Jaworski (1997) demonstrate that this can create “stronger market orientation, an increased ability to cope with complex dynamic environments, and greater new product success.”

While the majority of literature focuses on University based TTOs, TTOs in federal laboratories face the same marketing issues. A focus on patent filing and prosecution taxes the already limited resources in many federal TTOs, as well as the federally funded technology development efforts that take place in universities. This requires a low cost, easily accessible means of supporting market research and marketing efforts to improve successful transfer activities.

2. Model-Based Systems Engineering and Technology Marketing

The use of MBSE in support of marketing was discussed by Vollerthun in 2002. Vollerthun recognized that one of the major problems companies across all industries experience is that products do meet essential customer requirements in the target market segment. To counter this, his work attempted to build an integrated model. This model would represent the interrelations between life-cycle cost, market revenues, and conceptual design. Additionally, and in line with Fisher’s work, Vollerthun’s model sought to establish a communications link between engineers and marketers. The integrated model becomes the communications link that allows for idea exchange and an understanding of how changes affect each other (Vollerthun 2002).

A model-based approach is logical, because typically models are well understood and well-practiced in R&D focused organizations that work within the scientific and mathematical space (Dickerson and Mavris 2013). Additionally, models serve not only as representations of the system, but also work to suppress details that are not of interest (Dickerson and Mavris 2013), which can benefit cross-communication between different stakeholders. Models can also work to provide a common framework that incorporates differing points of view with equal rigor (Marquez and Blanchar 2006).

Vollerthun's model combines three separate subroutines. The model designed by Vollerthun "consists of a model to do the conceptual design, of a model that relates this concept to the cost that it defines, and, third, of a market model, determining what revenues can be generated" (2002, 322). "By integrating these three dimensions into one design methodology, integrated business case analyses can be performed in a much more effective way" (Vollerthun 2002, 322). This powerful tool allows for various design concepts to be examined, as well as sensitivity analysis within those designs (Vollerthun 2002).

Dickerson and Mavris provided a history of MBSE, and a summary of MBSE methodologies and commercial tools in 2013. Their work demonstrates that one of the commonalities across many of the methodologies discussed is a focus on requirements and functionality. Additionally, their previous work on relational oriented systems engineering (ROSE) also addresses requirements and functionality by providing a model of the problem space and a model of the solution space (Dickerson and Mavris 2011). Both the Vollerthun and Dickerson models accept user requirements as inputs to the model and provide conceptual design changes as outputs. These can be used to provide valuable information into system design for high technology inventions that are being transferred into the commercial space through technology transfer activities.

3. The Department of Defense Architecture Framework

The DoDAF Version 2.02 is the current version of the Department of Defense Architecture Framework and was released in August of 2010, with the intention of ensuring "reuse of information and that architecture artifacts, models, and viewpoints can be shared with common understanding" across the many DoD Commands (Chief Information Officer

2010a). This common understanding allows for DoD managers at all levels to make decisions more effectively due to a more organized means of information sharing. Version 2.02 of the DoDAF is more focused on "data" than previous versions and is designed to provide "an architectural description consistent with specific project or mission objectives" (Chief Information Officer 2010a).

The DoDAF Version 2.02 organizes all of its described models into eight "viewpoints." The eight DoDAF viewpoints, and what they are intended to describe, are:

- The All Viewpoint describes the overarching aspects of architecture context that relate to all viewpoints.

- The Capability Viewpoint articulates the capability requirements, the delivery timing, and the deployed capability.

- The Data and Information Viewpoint articulates the data relationships and alignment structures in the architecture content for the capability and operational requirements, system engineering processes, and systems and services.

- The Operational Viewpoint includes the operational scenarios, activities, and requirements that support capabilities.

- The Project Viewpoint describes the relationships between operational and capability requirements and the various projects being implemented. The Project Viewpoint also details dependencies among capability and operational requirements, system engineering processes, systems design, and services design within the Defense Acquisition System process. An example is the Vcharts in Chapter 4 of the Defense Acquisition Guide.

- The Services Viewpoint is the design for solutions articulating the Performers, Activities, Services, and their Exchanges, providing for or supporting operational and capability functions.

- The Standards Viewpoint articulates the applicable operational, business, technical, and industry policies, standards, guidance, constraints, and forecasts that apply to capability and operational requirements, system engineering processes, and systems and services.

- The Systems Viewpoint, for Legacy support, is the design for solutions articulating the systems, their composition, interconnectivity, and context providing for or supporting

> operational and capability functions. (Chief Information Officer 2010a)

Within these viewpoints exists 52 systems engineering-based models that can be used to describe the operational and functional capabilities of a system or technology. It is this specificity to operational and functional capabilities that allows for the viewpoints to support technology marketing for technology transfer activities and the early stages of new product development required for a commercial partner to successfully launch a new product in the commercial market. Souder, Nasher, and Padmanabhan describe the four technology transfer stages as:

> - Prospecting (Stage I…)…research, analytical, and decisionmaking activities aimed at screening alternative concepts or technologies and selecting the ones that fit the users' requirements.
> - Developing (Stage II)…physical and laboratory R&D activities focused on enhancing, elaborating, embodying, and tailoring the selected technologies from Stage I to meet the users' requirements.
> - Trial …(Stage III), the developed technologies are field tested.
> - Adoption …(Stage IV)…final development, technology modification, and user implementation activities. (1990, 5-6)

It is important to note that three of the four stages (Stages I, II, and IV) are aligned to address the final customer's use (Souder, Nasher, and Padmanabhan 1990). Understanding the customer's needs, requirements and intended use are important not only supporting technology transfer activities, but also the industry partner's new product development activities. As demonstrated earlier, MBSE provides an excellent platform for identifying user needs and ensuring designed-in functionalities meet these needs. Additionally, MBSE can provide in-depth descriptions regarding the operational and functional capabilities that support these needs.

4. New Product Development

In 1988's "The New Product Process: A Decision Guide for Management" Cooper presented his research into why new products succeed or fail (Cooper 1988). Then in 1996 Cooper presented a study that described the three cornerstones to successful product development in “Overhauling the New Product Process” (Cooper 1996). In both of these studies, Cooper describes the importance of product design based on user needs and input (Cooper 1988) (Cooper 1996). These points are additionally emphasized in later studies, such as the 2004 paper “The Formation of High-Tech University Spinouts: The Role of Joint Ventures and Venture Capital Investors” written by Wright, Vohora, and Lockett (2004).

Wright’s study presented a comparison between two university-industry formed joint ventures spinouts (JVSOs). As a result of this study, Wright, Vohora, and Lockett identify the need for a high level of understanding of market intelligence and user needs to support successful technology transfer activities. Furthermore, it was found that the JVSOs demonstrated to be more attuned to how commercial research could serve unmet customer needs than academic entrepreneurs were (Wright, Vohora, and Lockett 2004).

However, it is important to begin these efforts as early in the development cycle as possible. As noted by Mowery, civilian spinoffs associated with defense efforts “appear to be most significant in early development” (2009, 457. Early development phases “often exhibit substantial overlap between defense and nondefense applications,” but the requirements often diverge as the technology matures (Mowery 2009). The later sections of this paper will provide examples that can provide a low-cost means of capturing these operational requirements in systems engineering models to enhance these technology transfer activities with commercial partners.

Robert Carr, in “Doing Technology Transfer in Federal Laboratories (Part 1)” describes two types of technology transfer in federal laboratories; technology-pull, the case in which private industry “pulls” a technology from a research laboratory into the commercial market, and technology-push, when a research laboratory promotes a technology for which a market exists. While Carr singles out technology-pull as the more desirable, he acknowledges that technology-push is the more common pathway. Carr also notes the significant marketing efforts required to support “technology push” technology transfer efforts (Carr 1992a). In “Menu of Best Practices in Technology Transfer (Part 2),” Carr describes the technology-marketing process as “resource intensive and costly” (Carr 1992b).

Carr describes marketing-model technology-transfer offices as those that "actively market technologies available for licensing," and notes that most of the leading university T2 offices utilize some variant of the marketing-model (Carr 1992a). Carr describes two types of marketing opportunities for federal laboratories. The first is the marketing of available technologies, in-line with marketing-model universities and laboratories; while the other is marketing of the federal laboratory itself, to industry segments that are unaware of, or reluctant to participate in technology transfer activities with a federal laboratory (Carr 1992a). The following section will focus on the first opportunity but could (of course) work to support the second opportunity as well.

C. POTENTIAL DODAF SYSTEMS-ENGINEERING-BASED MODELS

In this section, six DoDAF models are presented for possible inclusion in technology transfer activities. Although many of the DoDAF described models could be used successfully in technology transfer activities, the six provided here were selected due to their strong alignment to technology transfer activities. The six models described here are (Chief Information Officer 2010a):

- CV-2: Capability Taxonomy: "a hierarchy of capabilities" which "specifies all the capabilities that are referenced throughout one or more architectures" (Chief Information Officer 2010c).

- CV-6: Capability to Operational Activities Mapping: "a mapping between the capabilities required and the activities that enable those capabilities" (Chief Information Officer 2010c).

- OV-1: High-Level Operational Concept Graphic: "the high-level graphical/textual description of the operational concept" (Chief Information Officer 2010d).

- OV-5a: Operational Activity Decomposition Tree: "the capabilities and activities (operational activities) organized in a hierarchal structure" (Chief Information Officer 2010d).

- OV-5b: Operational Activity Model: "the context of capabilities and activities (operational activities) and their relationships among activities, inputs, and outputs; Additional data can show cost, performers, or other pertinent information" (Chief Information Officer 2010d).
- SV-5a Operational Activity to Systems Function Traceability Matrix: "a mapping of system functions (activities) back to operational activities (activities)" (Chief Information Officer 2010e).

These models were chosen because they focus on the capabilities and operational activities of the technology or system being considered for technology transfer. The visualization of operational activities and capabilities provides a basis for Souder's first stage of Prospecting (Souder, Nasher, and Padmanabhan 1990). Modeling provides an inexpensive means of vetting technologies against user needs or requirements, without investing in prototyping or manufacturing costs. Together these models can help to not only describe the capabilities provided, but also the operational activities required to achieve these capabilities. This allows for down-selection activities at low cost to the federal laboratory. Additionally, these models provide the inputs for Vollerthun's model; i.e., the product characteristics, which in combination with weighting factors can be used to determine the value benefit (2002). This will allow for the commercial partner to analyze design alternatives against forecasted cost-benefit ratios (Vollerthun 2002). It is useful to note that these models can also support Suh's Axiomatic design theory for optimizing system design towards commercialization efforts (Suh 1998).

Innoslate version 4.0 was used to produce the DoDAF described viewpoints presented here. Innoslate combines Requirements View with Monte Carlo and Discrete Event simulators with standard SysML and LML in a Product Lifecycle Management tool. The models presented are purposefully kept simple, as the intent of this paper is not an in-depth study of the models, but rather a description of how such models can support technology transfer activities.

The six models presented here represent three different DoDAF viewpoints; Capability Viewpoint, Operational Viewpoint, and Systems Viewpoint. The capability viewpoint (CV) models describe capability taxonomy and capability evolution and are designed to provide visualizations of the technology's evolving capabilities. The models within this viewpoint can be used to show how a mission is supported by a capability or the predicted outcomes (Chief Information Officer 2010c).

The operational viewpoint models put the capabilities described in the capability viewpoint models in the context of an operation or scenario. When combined with effective interactions with the customer, these models can also be helpful in the defining the user requirements (Chief Information Officer 2010d). Lastly, the systems viewpoint (SV) models describe systems and interconnections that support the technology's functions. The models within this viewpoint associate resources to the operational and capability requirements of the technology and describe system-based solutions for requirements created by the operational development process (Chief Information Officer 2010e). Figure 15 shows the first viewpoint example, a CV-2 model, depicting the capability taxonomy of an energetic desensitizing agent patented by NSWC IHEODTD. This patented technology is described in US Patent Number 9,944,570 (Basom and Milani 2018).

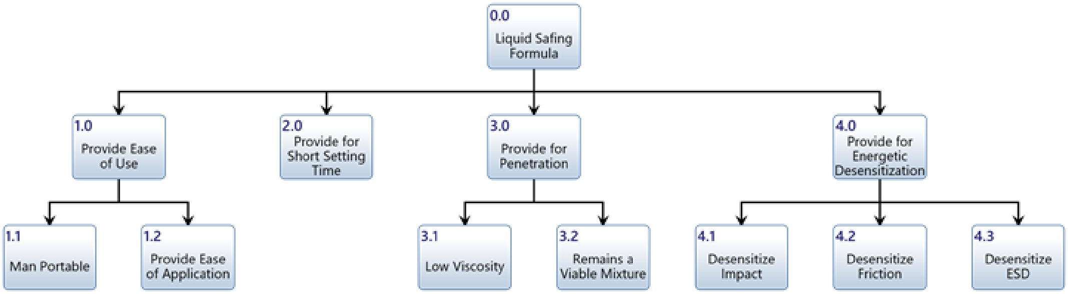
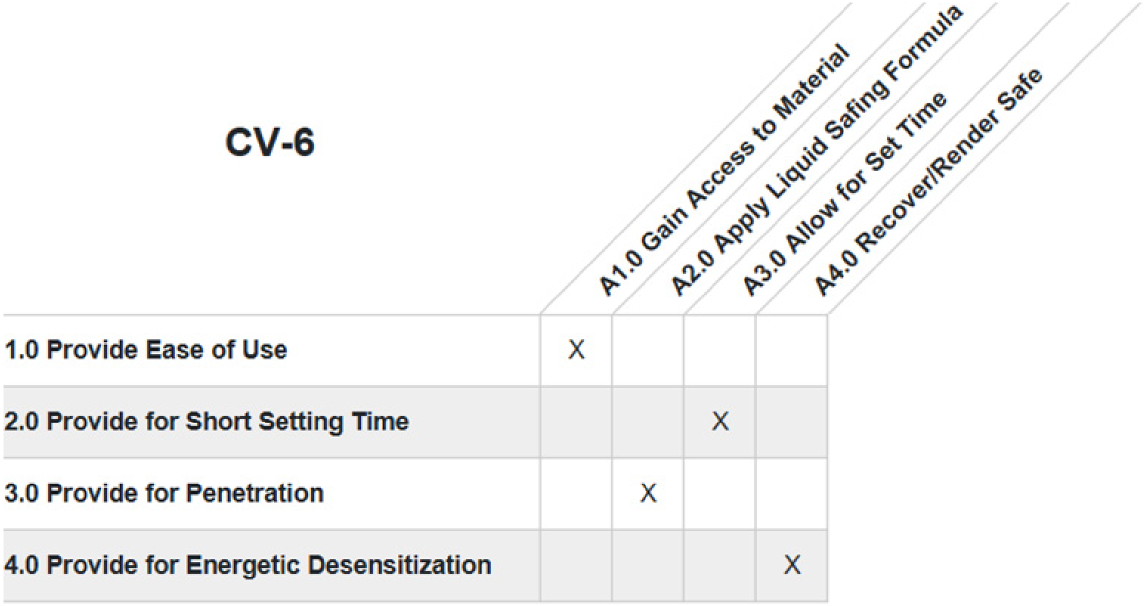


Figure 15. CV-2 Capability Taxonomy for Desensitizing Agent for Homemade and Conventional Explosives.

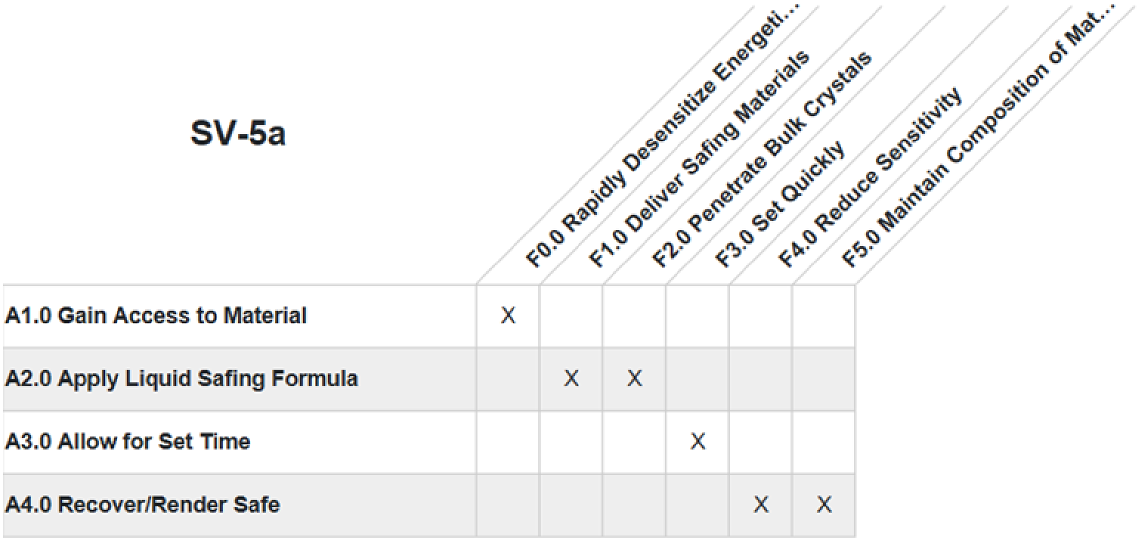
The CV-6 model, shown in Figure 16, which maps the desensitizing agent capabilities to the operational activities; and the SV-5a, shown in Figure 17, which maps the desensitizing agent's functions back to the operational activities; further supports Souder's second stage of enhancing or tailoring the technology to meet the user's requirements (Souder, Nasher, and Padmanabhan 1990). By mapping capabilities and functions to operational activities the CV-6 and SV-5a describe not only what user needs can be met through each function, but also what activities must be performed operationally to meet those needs, as well as providing insight into how the technology can improved or altered to better serve the customer. This can allow for needs-based design improvements in the early stages of the technology transfer process. These design changes can be identified in multiple ways, but sensitivity analysis as described by Dickerson and Mavris in "Relational Oriented Systems Engineering (ROSE): Preliminary Report" are two possible means of optimizing design trade-offs (Dickerson and Mavris 2011).



CV-6

	A1.0 Gain Access to Material	A2.0 Apply Liquid Safing Formula	A3.0 Allow for Set Time	A4.0 Recover/Render Safe
1.0 Provide Ease of Use	X			
2.0 Provide for Short Setting Time			X	
3.0 Provide for Penetration		X		
4.0 Provide for Energetic Desensitization				X

Figure 16. CV-6 Capability to Operational Activities Mapping for Desensitizing Agent for Homemade and Conventional Explosives.



SV-5a

	F0.0 Rapidly Desensitize Energeti...	F1.0 Deliver Safing Materials	F2.0 Penetrate Bulk Crystals	F3.0 Set Quickly	F4.0 Reduce Sensitivity	F5.0 Maintain Composition of Mat...
A1.0 Gain Access to Material	X					
A2.0 Apply Liquid Safing Formula		X	X			
A3.0 Allow for Set Time				X		
A4.0 Recover/Render Safe					X	X

Figure 17. SV-5a Operational Activity to Systems Function Traceability Matrix for Desensitizing Agent for Homemade and Conventional Explosives.

The Operational Viewpoints are helpful in Carr's concept of technology-push activities. Carr refers to the expense of technology-push activities and technology-marketing (Carr 1992a). MBSE is a regularly used technique within most DoD laboratories, and modeling provides for inexpensive alternatives to prototypes or production models. Furthermore, the routine nature of these models provides that they can be built in relatively short times, with low labor costs. MBSE is a means to realize large costs savings over the other tactics employed by marketing-based technology transfer offices; such as hiring staff with marketing experience or patenting a large number of technologies (Carr 1992a). Figure 18 is an OV-5a, or Operational Activity Decomposition Tree, and Figure 19 contains an Operational Activity Model, or OV-5b.

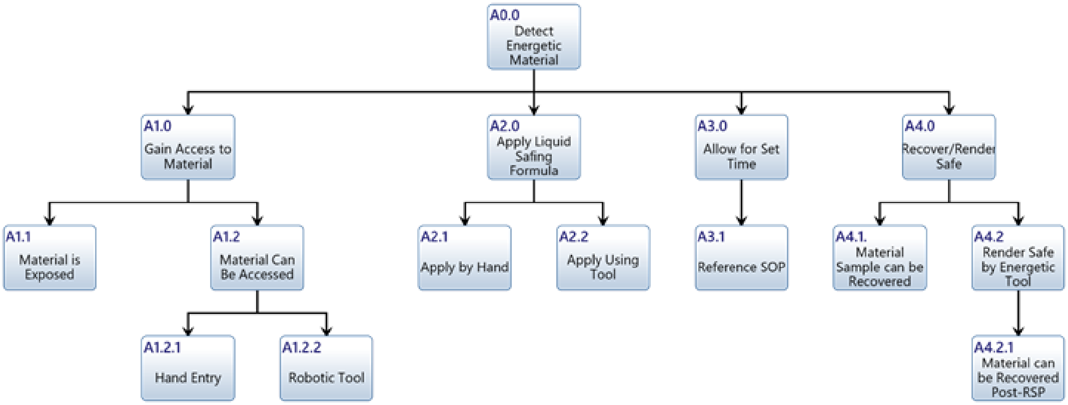


Figure 18. OV-5a: Operational Activity Decomposition Tree Depicting the Capabilities and Activities (Operational Activities) Organized in a Hierarchal Structure for Desensitizing Agent for Homemade and Conventional Explosives.

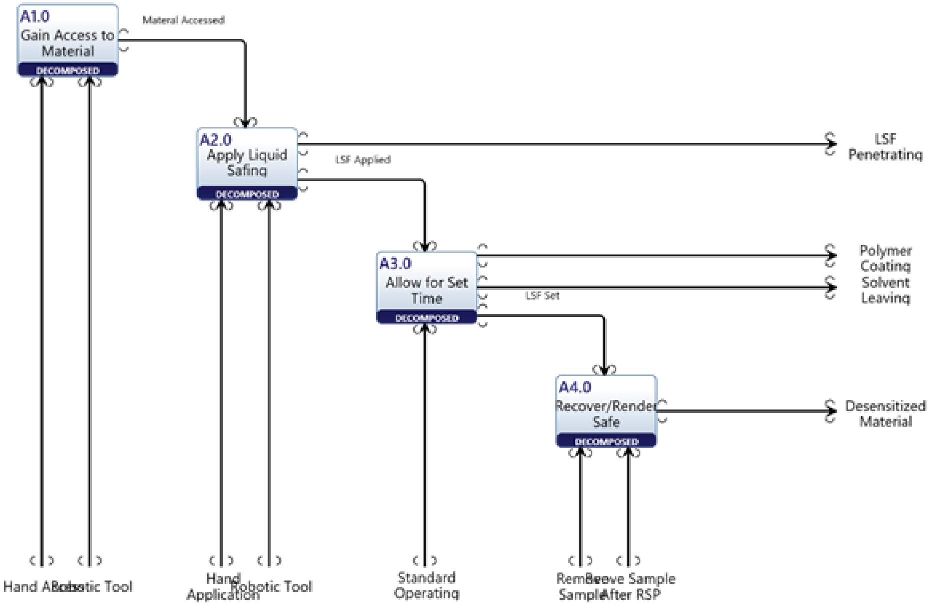


Figure 19. OV-5b: Operational Activity Model Providing the Context of Capabilities and Activities and Their Relationships Among Activities, Inputs, and Outputs for Desensitizing Agent for Homemade and Conventional Explosives.

D. DISCUSSION

The viewpoints and models selected here can be used to holistically describe a government-designed technology to potential commercialization partners in a way that demonstrates how that technology addresses operational requirements through system capabilities. As mentioned earlier, these models can also be used to suppress information that is not of interest/relevant, and allowing for a more focused and effective technology description. Additionally, these models directly address Souder's first two stages of technology transfer, prospecting and developing (Souder, Nasher, and Padmanabhan 1990). DoDAF models can provide for an inexpensive means of screening multiple technologies that can potentially address a user's requirements, as well as identifying potential enhancements or ways to tailor the technology to better meet the user's requirements, such as through sensitivity analysis.

The DoDAF Version 2.0 was designed to support several core processes within the DoD. Several of these align to the activities typically associated with technology transfer, and further demonstrate the usefulness of these models in support of T2. The DoDAF was established to help ensure that the warfighter receives the capabilities required to execute their mission, which is applicable to ensuring that commercial users receive the capabilities required for their needs as well. Understanding and addressing user requirements are not only key to Souder's methods, but those of Cooper's new product development as well (Souder, Nasher and Padmanabhan 1990; Cooper 1988). The use of DoDAF models allows for design changes to be identified through sensitivity analysis that will better support commercial market needs (dual-use technology), as well as accurately describing the market space and market value for commercialization partners.

DoDAF v 2.0 was also established to improve government investments in and guide the development of technologies to achieve capability. The use of the DoDAF viewpoints provides federal laboratories and their industry partners an opportunity to better understand how dual use technologies can address the capability needs of commercial customers as well as warfighter needs. Furthermore, when used with other MBSE models, they can provide useful information regarding return-on-investment and allowing for need-based design considerations in both markets (Fisher, Maltz, and Jaworski 1997; Marquez and

Blanchar 2006; Chief Information Officer 2010). Additionally, modeling is an inexpensive and well-understood means to achieve to this.

Additionally, MBSE can be a tool that easily identifies design, performance, or schedule deficiencies. “A Brief History of Models and Model-Based Systems Engineering and the Case for Relational Orientation” discusses several techniques to achieve these goals (Dickerson and Mavris 2011). This can be especially valuable when a technology transfer partner is a small business, start up, or joint venture. Identifying cost savings or performance improvements early, along with understanding the market and capability needs, can play a decisive role in the success of a new product (Cooper 1988).

MBSE should also be employed as early in the technology transfer process as possible. Early development phases not only provide the greatest amount of overlap between DoD and non-DoD applications, but will also provide for the most developmental flexibility (Mowery 2009). Again, as these techniques are often practiced regularly in DoD research laboratories, this should not result in significant increases in time or labor.

MBSE can play an important role in increasing both the TTO’s and commercial partners understanding of the technology and being transferred and the capabilities that the technology provides. This understanding is essential to improving the efficiency and effectiveness of T2 activities. Greiner and Franza have noted that understandable, demonstrable, and unambiguous technologies are easier to transfer. However, when a new technology’s capabilities are not well understood is when barriers arise in technology transfer and development activities (Greiner and Franza 2003).

The United States Marine Corps has begun to employ a MBSE approach to acquisitions. One of their goals in doing so is to better understand the relationships between cost, schedule, risk, and performance before major costs are incurred or requirements finalized (Smerchansky n.d.). These efforts serve as an important parallel to the methodology described herein. By engaging in the use of standard MBSE with technology transfer efforts, federal laboratories can facilitate a more streamlined process for the commercialization of federally developed technologies. In the case of dual use technologies, this process can allow for a merging of warfighter and commercial needs, followed by sensitivity analysis and trade-off modelling to optimize the technology for either customer. This could be leveraged to provide a standard procedure for the warfighter to generate requirements and facilitate the synchronization of technology transfer and development activities that not only provide a commercial market value, but also become available to the warfighter on a shortened time-scale through the commercialization process.

Finally, the DoDAF described models can assist the technology transfer office in the common activities of advertising and technology-push. These models, being readily available and inexpensive to produce, provide a means to address Carr's concerns regarding the cost of marketing. Figure 20 depicts an Operation Viewpoint 1 (OV-1) for the liquid safing formulation described earlier. This simple model is able to describe the operational concept of the LSF, and how the LSF interacts with the outside environment (Chief Information Officer 2010d). It is a low cost means of describing some of the operational capability and unique operational aspects of this technology.

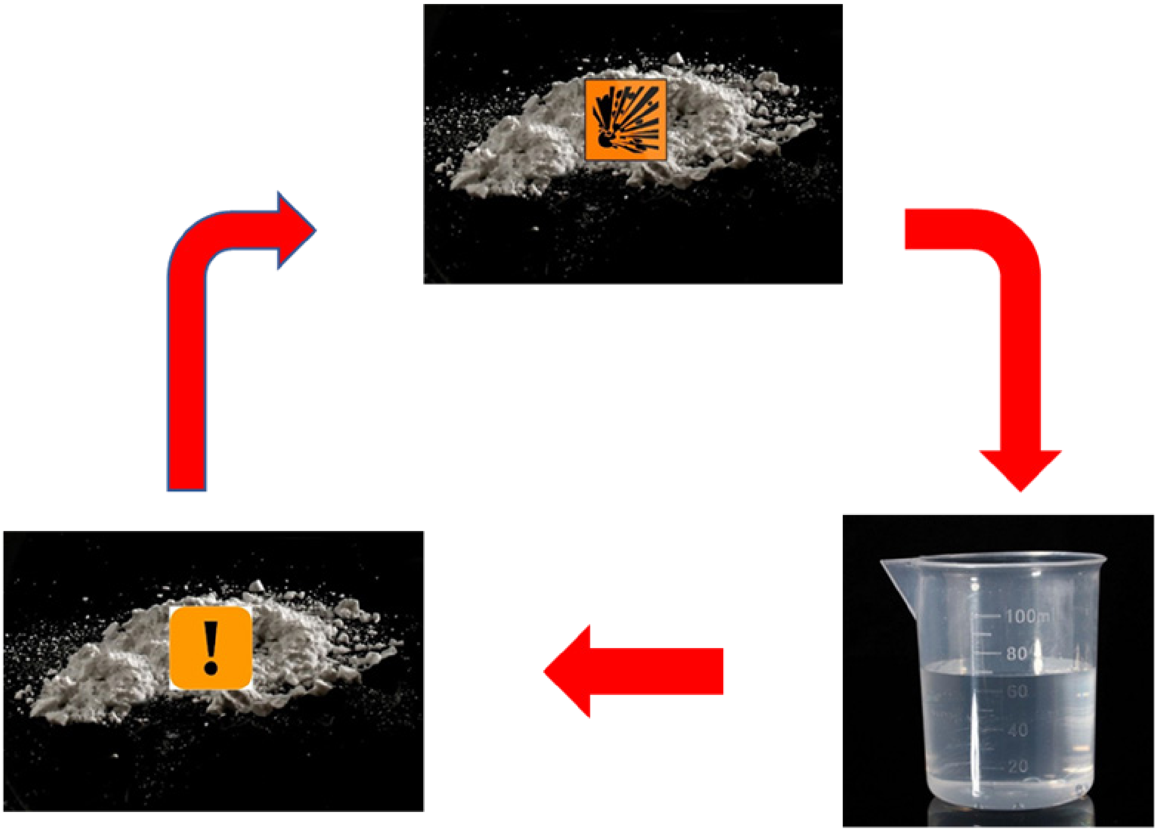


Figure 20. OV-1: High Level Operational Concept Graphic for Desensitizing Agent for Homemade and Conventional Explosives.

The models described herein can also be combined to provide additional information for technology transfer activities and potential commercial partners. For example, Figure 21 depicts a combined OV-5b/OV-6c, which work together to form an action diagram. The OV-6c is called an Event-Trace Description. This viewpoint is one of three models used to describe activity, and it specifically describes operational activity. The OV-6c traces actions in a sequence of events or scenario. The combined OV-5b/OV-6c can be used by the federal laboratory or transition partner to simulate operational activities in either discrete simulations or Monte Carlo simulations, providing further insight into operational activities to support market research and user requirements (Chief Information Officer 2010d).

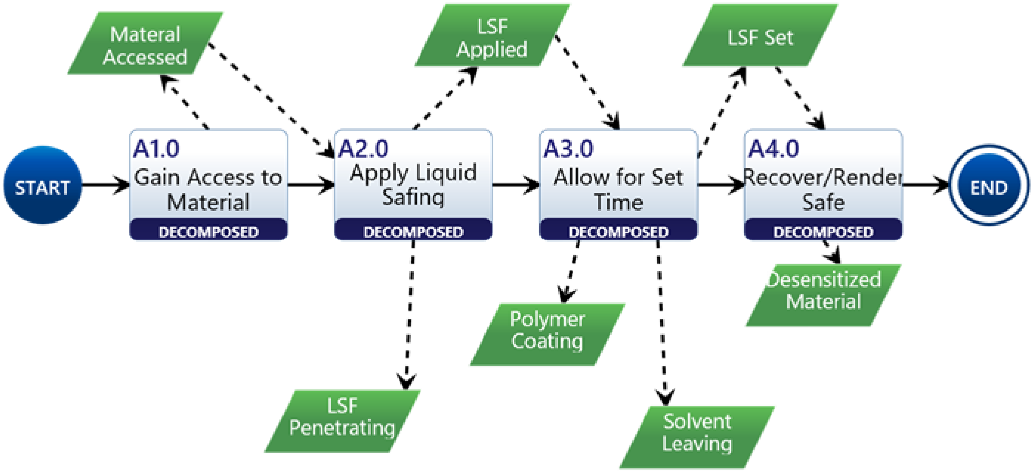


Figure 21. Combined OV-5b/OV-6c: Activity Diagram for Desensitizing Agent for Homemade and Conventional Explosives.

For marketing purposes, the DoDAF Version 2.0 also provides for an Overview and Summary Information format, in the All Viewpoint model AV-1. The AV-1 is a “structured text product” that provides a “consistent form that allows quick reference and comparison” (Chief Information Officer 2010b). It is often used to describe the concepts that are contained visually in an OV-1, and therefore a perfect choice for technology transfer activities. Each of a laboratory’s technologies can be describes in a similar textual format, using DoDAF described models to visual the operational/functional/capability connectivity’s of those technologies, providing easy access to information for potential commercialization partners. This will allow for quick down selection against user or market needs, and rapid, low risk developmental projects in new product development efforts.

DoDAF viewpoints should be routinely created for all patented technologies that are available for licensing from federal laboratories. This will establish and ensure communication between the inventors and the technology transfer officers and ensure a common understanding of the technology by all parties via the model development. The viewpoints should be provided to commercialization partners as part of the technology transfer package. This will ensure a common understanding of the technology between the TTO and commercialization partner. If, and when, appropriate the federal laboratory TTO should work with the commercialization partner to optimize the technology for the market through MBSE. This will serve to reduce the risk realized by the commercialization partner and improve chances for a successful product launch. Regular communication between the research laboratory and commercialization partner should be maintained to explore future “spin out” “spin in” opportunities.

E. CONCLUSION

Technology transfer offices are under increasing scrutiny to improve effectiveness, efficiency, and ROI. However, they are also tasked with a mission that is, by its very nature, expensive and difficult. Additionally, many TTOs are underfunded. This requires TTOs to seek out inexpensive and readily available tools that support their mission and require a minimum investment in terms of both funding and time. The DoDAF Version 2.0 viewpoints and models can provide federal laboratories with such tools. Federal laboratories employ many systems engineers and systems architects that understand and employ these models on a regular basis. Training for TTO staff on the use of these models is also readily available in most laboratories.

The benefits of using these viewpoints and models to support to technology transfer activities is obvious. The ability to model a technology in a way that identifies the capabilities provided, mapped to the components and operational activities provides simple means to describe how that technology can be used to fill an identified market need or gap in a commercial market. It provides potential commercial partners an easy way to evaluate the technology being considered for transfer for a future development effort to enhance the provided capabilities. Additionally, it offers a process for the warfighter to nominate requirements, that can be evaluated along with commercial requirements to synergize technology transfer and development activities of dual-use technologies. These models can help to keep costs down for smaller transition partners at crucial times in the new product development process, lower risk for commercial partners, work to ensure successful product launch activities, and integrate/synergize the warfighter-to-product development activities.

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V. IMPROVED TECHNOLOGY TRANSFER METHODOLOGY BASED ON SYSTEMS ENGINEERING TECHNICAL REVIEWS

A. INTRODUCTION

The use of PLAs to foster Technology Transfer (T2) activities by federal laboratories is rooted in legislation from the middle of the last century. In 1950, Executive Order 10096, signed by President Truman, established federal policy under which all inventions made by government employees within the scope of their work responsibilities will assign all rights to the U.S. Government (Exec. Order No. 10096, 3 C.F.R. (1950)). This was followed by the Steven-Wydler Technology Innovation Act of 1980, which required federal laboratories to participate in Technology Transfer (T2) activities (Stevenson-Wydler Technology Innovation Act of 1980, 15 U.S.C. § 3701 (1980)). Finally, the Bayh-Dole Act of 1980 focused on the use of licensing agreements to facilitate T2 activities and encourage maximum participation by small business (Bayh-Dole Act of 1980, 35 U.S.C. § 200 (1980)). These federal statutes and executive orders not only encourage the practice of technology transfer by federal laboratories, but in fact require it. As such, it is the responsibility of all federal laboratories to patent any intellectual property developed under federal funding, and to make these patents available for licensing by private industry partners, not for profits, and academia through licensing agreements.

Although these T2 activities are required, each laboratory is free to execute its individual technology transfer program as they see fit. As such, there are few established methodologies for how to routinely engage in licensing activities to achieve maximum benefit for federal research programs and leverage, to the maximum amount possible, the investment of U.S. tax dollars in federal research programs. Herein is described a methodology, built on previous technology transfer and new product development methods, for routinely engaging in technology transfer activities in such a way as to minimize the risk realized by commercialization partners and increase the chance of successful technology transfer efforts. This methodology incorporates the use of well understood and widely practiced systems engineering technical reviews to establish evaluation points at which the laboratory and industry partner can make GO/KILL/HOLD decisions regarding the technology transfer effort to best leverage resources and reduce risk in these activities.

B. LITERATURE AND BACKGROUND

The Stage-Gate process was established as formal, methodical process for new product development by Robert Cooper in the 1980s. For the past 30+ years a variety of business methodologies have been based on Cooper's work focusing on wide variety of business needs. These have included new product development, technology transfer, life sciences, and open innovation (Cooper 1996; Jagoda, Maheshwari, and Lonseth 2010; Soenksen and Yazdi 2017; Grönlund and Frishammar 2010). Cooper's early investigations focused on key activities that were necessary and possibly missing from new product processes in industry (Cooper 1988, 240–241). Additionally, Cooper also identified the need for evaluation points, or "Gates" to serve as points where a "GO", "KILL", or "HOLD" decision can be made, and also serve as checkpoints to evaluate the quality of the execution of process activities (Cooper 1988, 240–241). This work lead Cooper to establish a systematic new product process: the Stage-Gate Process.

Grönlund and Frishammar built on Cooper's work to describe a methodology for open innovation. Their model leverages the benefits of open innovation (Grönlund and Frishammar 2010, 107). The Grönlund and Frishammar model also "minimizes the associated risks, and allows systematic evaluation and reconfiguration of the way value is created and captured through NPD" (Grönlund and Frishammar 2010, 107). This method is similar to the method described previously by Jagoda, Maheshwari, and Lonseth, which provides a technology transfer methodology for use by small and medium business. Jagoda's method is also modeled after Cooper's Stage-Gate methodology. The work of both Cooper, Grönlund, and Jagoda provide a private industry tie-in for the methodology describe herein.

Additionally, in 1990s "A Guide to the Best Technology-Technology Processes," Souder, Nashar, and Padmanabhan described a systematic technology transfer process that contained interactive stages of activities (1990). In the methodology described below, the authors recommend the use of "gateway decisions" in conjunction with Souder, Nashar, and Padmanabhan's systematic process to serve as decision points to increase the efficiency of technology transfer activities within DoD laboratories. These gateway decision points are modeled after four of the recommended System Engineering Technical Reviews and will serve to enhance the robustness of Souder, Nashar, and Padmanabhan's process. They are: initial technical review, alternative system review, test readiness review (optional), and system verification review (SVR).

The Systems Engineering Technical Review Process was developed by Naval Air Systems Command (NAVAIR), and has since been adopted throughout the Navy (SEDIC 2015). It was established to map the technical reviews to the acquisition process and provides a framework for structured systems engineering management. The SETR Process Handbook provides the following description for the four selected technical reviews.

The purpose of the initial technical review (ITR) is to understand the need for a materiel solution to close an identified capability gap. The technical review occurs before the materiel solution analysis (MSA). The ITR is designed to assess needs and the current state of technology (SEDIC 2015). The purpose of the alternative system review (ASR) is review the technical path forward for the preferred materiel solution. This technical review occurs after the analysis of alternatives and ensures that the preferred solution is agreed upon and the capability objectives and operational requirements are well defined (SEDIC 2015).

The Test Readiness Review is meant to assess both the product readiness and test objectives. The TRR is conducted during the engineering and manufacturing development (EMD) phase, prior to integrated testing. The TTR will evaluate test procedures and verify traceability to requirements (SEDIC 2015). Lastly, the SVR serves as a multi-disciplines product review to ensure readiness to enter low rate initial production (LRIP) and full rate production (FRP). The SCR starts with an audit of test results, and ultimately verifies final performance (SEDIC 2015).

C. METHODOLOGY FOR DOD TECHNOLOGY TRANSFER STAGE AND GATE

This section describes a new stage and gate methodology for use in federal laboratories. Figure 22 depicts the stages and gates, aligned to Souder, Nashar, and Padmanabhan's systematic process. This methodology provides for a technology transfer process that incorporate the rigor imparted through the systems engineering technical review process.

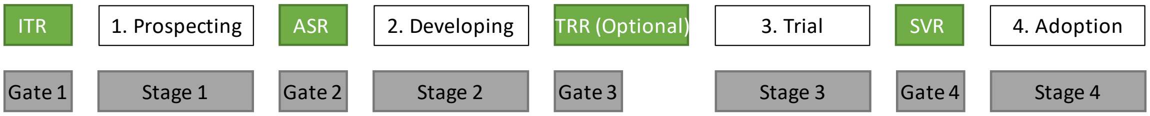

Figure 22. New Technology Transfer Stage and Gate Methodology. Adapted from Souder, Nashar, and Padmanabhan.

GATE 1

The first gate is modeled after an ITR as described in the "SETR Process Handbook." This gate is designed to assess the technology being screened against commercial needs and capability gaps. This effort will confirm or not confirm that the technology has the potential to effectively address these needs/gaps and provide the attributes desired by potential end-users and commercial partners (SEDIC 2015). Additional efforts by the TTO can consist of market discovery/identification and the identification of potential commercial partners.

Entrance Criteria:

- Any/all laboratory IP is properly protected.
- Technology is available for licensing.

Suggested questions for evaluation of this effort at Gate 1 are:

- What is the current TRL of this technology, intellectual property, or patent?

- What are the existing commercial needs that this technology, IP, or patent align to?
- What other technologies currently exist to fill these needs and who makes/sells them?

Suggested Outputs/Outcomes for Gate 1:

- Technical Review Summary Report, including identified needs/gaps.
- List of potential commercial partners.
- List of competing technologies.

STAGE 1

Stage 1 activities include research and analysis activities to screen alternative concepts and technologies (Souder, Nashar, and Padmanabhan 1990). The questions answered in Gate 1, as well as the Gate 1 outputs should be designed to aid potential commercial partners in the "Prospecting" stage and work towards lowering their risk in T2 activities with the laboratory. The end of this stage should realize the identification of a technology that can provide a viable commercial product to the industry partner.

GATE 2

The second gate is modeled after an Alternative Systems Review as described in the "SETR Process Handbook". This gate is designed to ensure that the selected system has the potential to resolve the required advanced technologies, employment concepts and user's needs. This effort will further lower the commercial partner's risk by confirming that the technology selection was appropriate or identify alternative designs that may improve effectiveness and trade studies (SEDIC 2015). Additional efforts by the TTO should include the establishment of a Commercialization Plan by the industry partner, and a fully negotiated and signed Patent License Agreement.

Entrance Criteria:

- Selection to proceed with government owned technology, IP, or patent.

- Cooperative Research and Development Agreement (CRADA) has been established with commercial partner.

Suggested questions for evaluation of this effort at Gate 2 are:

- Has the specific user need/gap been refined and agreed upon?
- Are there design changes that can be made to improve this concept/technology?
- How does the technology align to the operational requirements and capability objectives of the commercial partner?

Suggested Outputs/Outcomes for Gate 2:

- Comprehensive assessment and definition of the technology, operational requirements, and capability objectives.
- Systems Architecture models.
- Model-Based Systems Engineering models and views.
- Established Patent License Agreement.

STAGE 2

Stage 2 activities include physical and/or laboratory R&D efforts to advance the component or technology towards the user's needs (Souder, Nashar, and Padmanabhan 1990). The questions answered in Gate 2 and the Gate 2 outputs should support the commercial partner in the "Developing" stage by providing a comprehensive deconstruction of the technology and alignments of component to function and component to capability. Additionally, the partners should identify opportunities for collaborative development efforts that can be performed under the previously established CRADA. The end of this stage should realize the development of a prototype(s) that will support testing by the commercial partner. Options and possibilities for collaborative testing should also be identified, as these efforts may benefit both e commercial partner and the federal laboratory. If collaborative test and evaluation (T&E) of interest to both parties, then proceed into Gate 3, if the industry partner will be performing testing outside of a government partnership and the government is not interested in an independent test event, then Gate 3 may be omitted.

GATE 3

The third gate is modeled after a Test Readiness Review as described in the "SETR Process Handbook." This gate is meant to test the readiness of the technology and ensure that the test procedures are adequate to accomplish testing requirements (SEDIC 2015). This effort can support collaborative T&E (preferred) or government only testing to support government interests. As a collaborative effort, this gate could also be used to ensure rigor and robustness in the commercial partner's test efforts.

Entrance Criteria:

- Development of a prototype.
- Full understanding of user's needs, commercial gaps, operational requirements, and/or capability objectives.

Suggested questions for evaluation of this effort at Gate 3 are:

- Has any informal testing occurred, and what were the results?
- What is the current TRL of the component or technology, and what will it be upon test completion?
- What are the identified test procedures, and are they sufficient to support the verification of system requirements?

Suggested Outputs/Outcomes for Gate 3:

- technology is ready for testing.
- Test plans, methods, and procedures are identified and properly resourced.
- Test elements are traceable to operational requirements and user needs.

- Defined format and reporting process for test results.

STAGE 3

Stage 3 activities include test and evaluation of the technology (Souder, Nashar, and Padmanabhan 1990). This stage may be carried out and completed entirely by the commercialization partner, and therefore “skipped” by the federal laboratory partner; or it can be conducted in partnership. If the testing and evaluation are performed in partnership, they should be performed under the previously established CRADA to allow for data sharing and data protection among the partners. Also, if joint testing will be performed, it should be performed in the manner that was defined in Gate 3.

GATE 4

The last gate is modeled after a SVR as described in the “SETR Process Handbook”. This gate is meant assess the component or technology and test and evaluation results, to confirm that the system will meet performance requirements. This review must be multi-disciplined and assess whether the commercial operation capabilities or function requirements identified during technology transfer activities have any overlap with federal capability gaps or user requirements (SEDIC 2015). If any overlap is identified, this technology should be pursued as a dual-use technology and “spun in” to appropriate federal programs.

Entrance Criteria:

- testing complete
- final design

Suggested questions for evaluation of this effort at Gate 4 are:

- What were the results of test and evaluation efforts?
- Do any minor design changes need to occur?
- Do any of the technology’s capabilities or commercial user requirements align with federal capability needs or user requirements?

Suggested Outputs/Outcomes for Gate 4:

- All validation and verification activities have been completed.
- Assurance that all user requirements have been addressed.

STAGE 4

In Stage 4 the commercialization partner will finalize the design and any remaining modifications, as well as performing any user implementation activities (Souder, Nashar, and Padmanabhan 1990). This federal laboratory partner will be performing similar activities for "spin in" opportunities. The partners should continue the partnership in the out years of the commercialization effort, to afford for future knowledge sharing opportunities, collaboration on future technology improvements, and identification of other T2 opportunities. The benefits of continued collaboration cannot be overstated.

D. DISCUSSION

The success of SETRs is highly dependent upon the body of technical reviewers. Many federal laboratories have a panel of scientists and engineers that are used for evaluating invention disclosures developed within the lab. Typically, this panel consists of Subject Matter Experts with a variety of technical and experiential backgrounds, much in the same way that the SETR Process Handbook recommends for the makeup of a Technical Review Board (TRB) (SEDIC 2015). At NSWC IHEODTD, this panel is called the Invention Evaluation Board (IEB), and more than competent to serve as a TRB for the Gates identified in the previously described methodology.

The methodology presented in the previous section was designed to incorporate systems engineering rigor with common technology transfer activities into a process that supports Cooper's New Product Process. Figure 23 shows the alignment of these three methods. Once the federal laboratory has passed Gate 1 &2, a decision has been made to develop the government patented technology for use in a commercial market. The Gate 1 outputs will support Cooper's first stage of "Assessment," wherein a "preliminary market assessment" and "preliminary technical appraisal" of the technology can be performed (Cooper 1988). Gate 2 supports Cooper's "Definition" and "Development" stages through a comprehensive assessment of the technology, operational requirements, and capability objectives (Cooper 1988). Additionally, the production of systems engineering models will allow for a robust description of the technology in support of market research for product design and competitive analysis, as well further design efforts for improved commercial use.

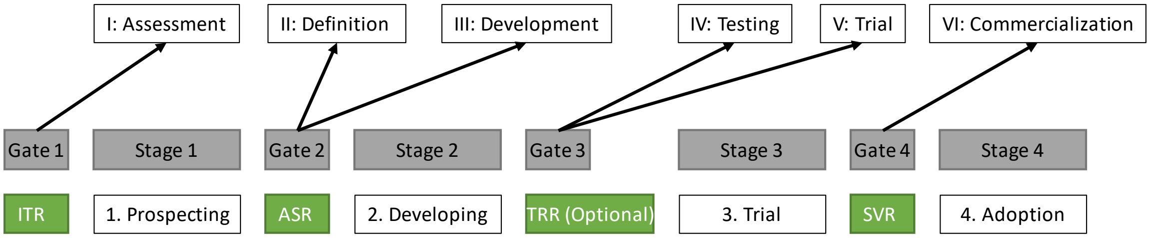

Figure 23. New Technology Transfer Stage and Gate Methodology Aligned to the New Product Process. Adapted from Cooper (1988).

The work products from the federal laboratories Gate 3 activities are designed to support Cooper's "Testing" and "Trial" stages (Cooper 1988). These work products will ensure that the necessary test resources will be available, and that the test and evaluation activities will properly measure the technology against identifies user needs, and operational and functional requirements. Collaboration is preferred in this stage, as dual-use should also be investigated during T&E and leveraging of federal and private industry resources should be maximized.

Gate 4 will ensure that a final design is identified, and that the final design meets all requirements. These outputs will support the commercialization partners' final efforts for product launch. Additionally, if the technology is going to made available to federal employees as a commercial off the shelf (COTS) item, the federal laboratory can make use of these work products to describe operational and functional capabilities to the warfighter and program officers. It is important, however, that an active and continued partnership be supported by partners for the purposes of monitoring future "spin in" opportunities, as well as the continued identification of technology transfer opportunities.

This methodology is also flexible enough to support other identified stage and gate methodologies. As Figure 24 demonstrates, the identified T2 methodology will also support Grönlund, Sjödin, and Frishammar's Open Innovation Stage-Gate process. Gate 1 will provide the information necessary to address Grönlund's first stage. The Technical Review Summary Report will aid in identifying whether the technology aligns with the commercial partners core capabilities and fits within their business model (Grönlund, Sjödin, and Frishammar 2010). The more comprehensive technology assessment and systems engineering models produced in the second Gate will support the second stage of Grönlund's methodology. This stage is beneficial for exploring whether the core capabilities of the business or the existing business models have any inherent deficiencies or limitations that need to be addressed. The operational and functional mapping providing by DoDAF v. 2.0 will allow the industry partners an increased fidelity at reviewing and assessing their own business models and allow for an improved analysis and trade-off studies for deciding on making improvements.

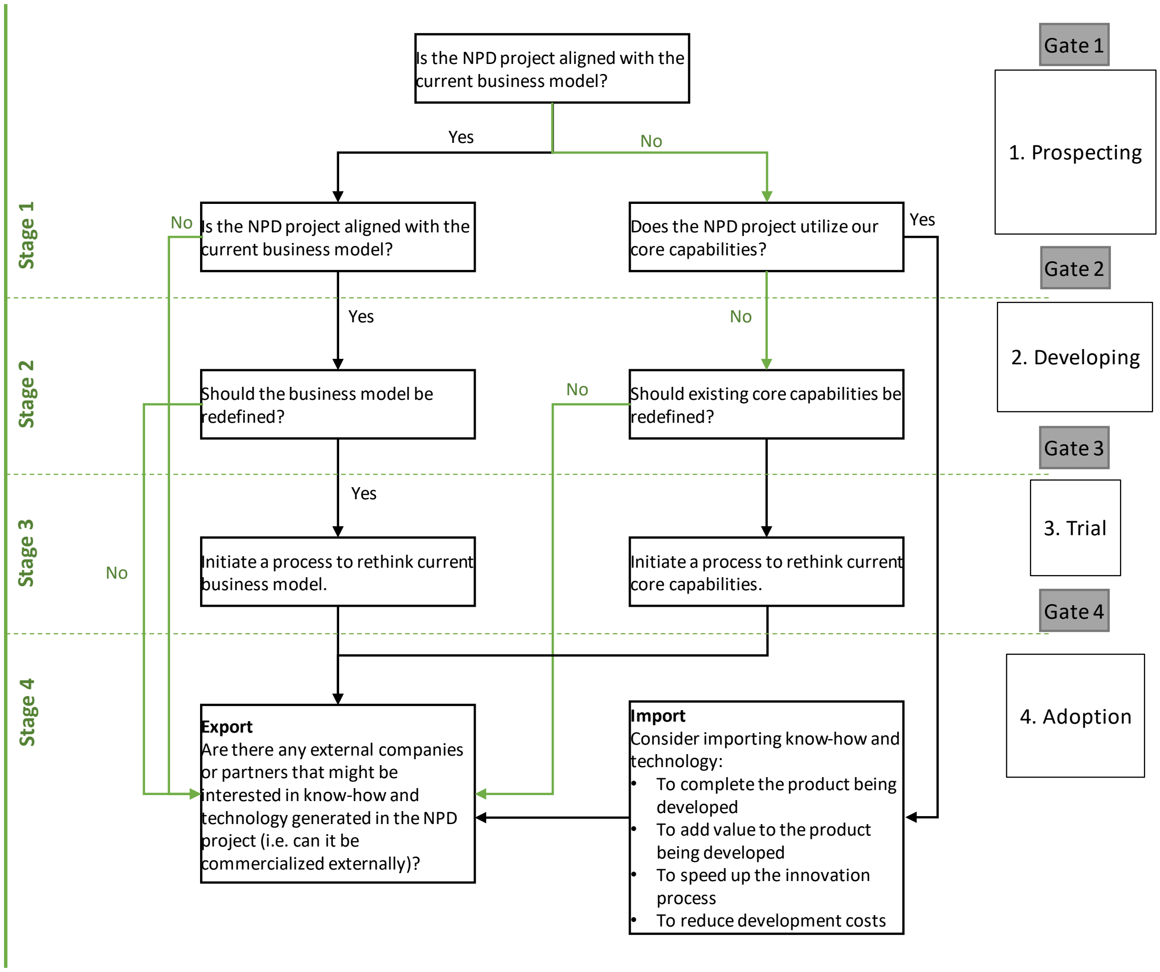

Figure 24. New Technology Transfer Stage and Gate Methodology Aligned to the Open Innovation Evaluation Criteria Decision Tree. Adapted from Grönlund, Sjödin, and Frishammar (2010).

Grönlund, Sjödin, and Frishammar's stage three focuses on initiating "a process to rethink current business model" and initiating "a process to rethink core capabilities" (2010, 120). As such, this stage is not greatly influenced by the improved technology transfer methodology. However, it is important to note that if the commercial partner decides to change their core capabilities and business model in support of a new product launch, it may be even more necessary for the partner to leverage federal laboratory expertise through collaborative T&E activities. Collaboration should be strongly considered. Stage 4 of the Grönlund, Sjödin, and Frishammar methodology focuses on "spin in" and "spin out" decisions. Grönlund, Sjödin, and Frishammar accurately describes the benefits of exploring "external paths to market," which allow for a company to profit through technology licenses (2010). The federal laboratory partner can benefit in similar ways, and all paths to market should be explored.

E. CONCLUSION

The methodology described here is based on Souder, Nashar, and Padmanabhan's work from the 1980s and early 1990s; but incorporates the rigor of a stage and gate process by incorporating Gates that are based on systems engineering technical reviews. Cooper demonstrated that a rigorous process can improve the chance of successful new product launch by 20% or more. It is reasonable to expect that a more rigorous technology transfer process will increase efficiencies in T2 activities and help to support the success of laboratory commercialization partners. By basing the Gates on well-known and oft-practiced SETRs, the federal laboratory further increases efficiencies, and the chance of success, based on the vast amount of experience and expertise within the laboratory.

Additionally, the proposed methodology is flexible enough to support to multiple new product development stage and gate methodologies. Flexibility is one key to the wide-spread use of any methodology; due to the wide variety of federal laboratory mission sets and products. Adaptability allows the individual TTOs to employ this methodology appropriately, while maximizing the systems engineering expertise available to them within the lab.

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VI. NAVAL SURFACE WARFARE CENTER INDIAN HEAD EXPLOSIVE ORDNANCE DISPOSAL TECHNOLOGY DIVISION TECHNOLOGY TRANSFER ACTIVITIES CASE STUDY COMPARISON

A. INTRODUCTION

The Federal Government has recognized the need for a partnership between the Federal Laboratory System and private industry entities since 1980. The Stevenson Wydler Technology Innovation Act of 1980 and later the Federal Technology Act of 1986 were the first major legislative steps in facilitating technology transfer activities from the government to private sector. These two acts are commonly referred to the Federal Technology Transfer Act (FTTA) and are now codified in Title 15 United States Code section 3715 (Erlich 2011, 17). This legislation enables a partnership between government and private enterprises to transfer government owned technology, services and property to the private sector for the purposes of commercialization and full-scale production. The legislation authorizes federal laboratories to enter into cooperative research and development agreements (CRADAs) with private enterprises and serves as a mechanism to transfer technology to the private sector (Erlich 2011, 17).

B. BACKGROUND

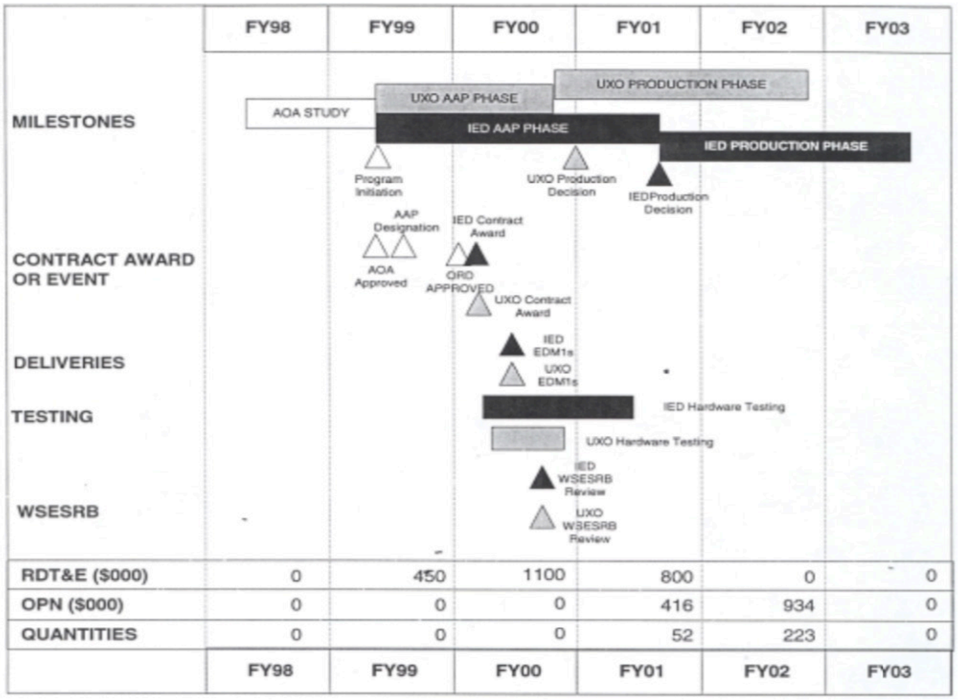
Although the legislative process has been available since 1980 to transfer government owned technology to the private sector, there have been challenges in executing this process in an effective, timely and standardized manner. There have been several attempts to improve the effectiveness and timeliness of technology transfer activities since 1980. Specifically, on March 7, 1996, President Clinton signed Public Law 104-113 to amend FTTA with respect to inventions made under CRADAs and for other purposes (Erlich 2011, 25). The intent of Public Law 104-113 was to streamline technology transfer commercialization and remove existing barriers by providing “incentives to both industry partners and Government personnel” (Erlich 2011, 17). In 2011, President Obama strived, “to establish goals and measure performance, streamline the administrative process, and facilitate local and regional partnerships in order to accelerate technology transfer and support private sector commercialization" (Obama 2011). Additionally, President Obama established the Interagency Workgroup on Technology Transfer, established by Executive Order 12591 of April 10, 1987, to seek "opportunities for improving technology transfer from Federal laboratories" and make recommendations to the Department of Commerce. The presidential memorandum directed an assessment of existing technology transfer programs effectiveness and standards, called for innovative and "creative approaches to technology transfer that might serve as model programs for Federal laboratories", required metrics for assessing "effectiveness and impact on the Nation's economy", and required an assessment of existing CRADA programs (Obama 2011). In 2016, before the United States House of Representatives Committee on Small Business, during a hearing on Commercializing on Innovation Reauthorizing the Small Business Innovation Research and Small Business Technology Transfer Program, the office of the Chief of Naval Operations (CNO), outlined changes to the acquisition process to decrease schedule and cost overruns while streamlining the requirement review and acquisition process. The report references the 2016 National Defense Authorization Act to "increase the Service Chiefs' authorities to manage trade-offs between costs, schedule, technical feasibility and performance by requiring Service Chief approval at key points. It also enhances Navy's ability to obtain and sustain the required technical expertise by increasing Service Chief's ability to manage acquisition career paths for military personnel" (DON 2016, 1). The report outlined a plan to link and streamline the requirements, acquisition, and budget process by establishing the Department of the Navy Six Gate Review process in 2016 (DON 2016). In 2017, President Trump established the White House OAI on March 27, 2017 to "make recommendations to the President on policies and plans that improve government operations and services…" (Trump 2017). Following the establishment of the OAI, the Trump administration released the President's Management Agenda in 2018. One of the priorities this agenda outlined was the improvement to "transfer of federally-funded technologies from lab-to-market" (Trump 2018). To do this, the agenda stated three goals; "improve the transition of federally funded innovations from the laboratory to the marketplace by reducing the administrative and regulatory burdens for technology transfer, develop and implement more effective partnering models and technology transfer mechanisms for Federal agencies, and enhance the effectiveness of technology by improving the methods and evaluating the ROI and economic and national security impacts of federally funded research and development" (Trump 2018).

The legal authority and mechanism to transfer government owned technology, services and property has been in effect since 1980. Since then, there have been several legislative improvements and presidential initiatives to further streamline and improve the effectiveness of this process. The authors of this thesis proposed the following question: if the legal authority to transfer government owned technology, services and property has existed since 1980, why has this process remained ineffective, costly and slow? The referenced initiatives by three presidents, Congress and the Department of the Navy, serves as evidence of the problem. Furthermore, the authors of this thesis hypothesize the problem with technology transfer activities is not one of legal substance, instead is one of process failure. Currently, there is not a standardized and widely utilized process to transfer technology from the government to private entities. For every transfer initiative, the federal laboratory individualizes a technology transfer strategy; this is costly and time consuming. Utilizing standardized model-based systems engineering practices and methodologies can be employed within federal TTOs to improve productivity. To illustrate this concept, the authors of this thesis will provide three examples of current and former technology development programs and provide a comparison of schedule, cost and technology transfer methodologies.

C. PERCUSSION ACTUATED NONELECTRIC DISRUPTER PROGRAM

The percussion actuated nonelectric (PAN) disrupter program was approved for development as an abbreviated acquisition program by the program executive officer, mine warfare (PEO MINEWAR) in April 1999 (Vaughn 1999). The need for a standoff disrupter capability existed within the joint EOD force because the EOD technician is required to render safe or disrupt unexploded ordnance (UXO) and improvised explosive devices (IED). At the time, the current render safe and disruption tools and techniques required the EOD technician to remain in close proximity to the hazard while positioning the tool. Additionally, the increased technological complexity of explosive hazards incorporating sensing devices required greater standoff by EOD technicians to avoid triggering of the munition. The additional standoff would decrease the probability of initiating UXO or IED devices by sensor activation and would increase the EOD technician's ability to engage the target from a protected position (Vaughn 1999).

The standoff disrupter program was initiated to develop a set of tools to render safe or disrupt UXO and IEDs from a standoff position outside the target's sensor range. The system was developed to replace two tools, the Mk 2 Mod 1 tool set (.50 caliber dearmer) and the Mk 31 Mod 1 tool set (JROD) (Kiser 1999). The .50 caliber dearmer was used to render safe a large variety of UXO and disrupt IEDs. The JROD was used to disrupt IEDs. Both tools needed to be placed within a few inches of the intended target, exposing the EOD technician to any initiation sensors the target contained and the full effects of blast overpressure resulting from a detonation (Kiser 1999). Standoff from the target would mitigate both hazards. The standoff disrupter was developed within the federal laboratory enterprise and transitioned to the commercial sector for production and fielding.



	FY98	FY99	FY00	FY01	FY02	FY03
RDT&E ($000)	0	450	1100	800	0	0
OPN ($000)	0	0	0	416	934	0
QUANTITIES	0	0	0	52	223	0

Figure 25. Integrated Standoff Disrupter Test Program Schedule. Source: Kiser (2000).

Figure 25 outlines the five-year development and initial operating capability test and validation plan for the standoff disrupter program. The program was initiated in fiscal year 1999 and designated as an abbreviated acquisition program for development. The acquisition strategy was to pursue the commercial item (dual tools) alternative as an abbreviated acquisition program as the most cost-effective approach (Kiser 2000). The standoff disrupter would require the initial commercial items to complete hardware testing, to include safety testing and obtain weapons system explosives safety review board certification prior to a production decision and initial operating capability production phase (Kiser 2000, II-1). As outlined in figure 25, \$2.35 million dollars for research, development, testing and evaluation (RDT&E) and \$1.35 million dollars for other procurement, Navy (OPN) was budgeted to be spent through the program development lifecycle. The standoff disrupter abbreviated acquisition program was initiated by the federal laboratory enterprise and transitioned to the commercial sector for development and production over the course of five years with an investment of \$3.7 million dollars for low rate initial production capability for Navy EOD (Kiser 2000).

D. SMALL ELECTRONIC COUNTERMEASURE VERIFICATION CAPABILITY PROGRAM

The electronic countermeasures (ECM) coverage verification situational awareness device is an ongoing technology development program proposed by the United States Marine Corps in 2012 and supported by the joint EOD military technical acceptance board (MTAB) in April 2016 (Kearney 2016). The Joint MTAB statement of need document of April 2016 identified the need to remotely verify whether an ECM system is “on” and radiating. The concept is outlined to provide EOD technicians situational awareness as to whether he/she is within close proximity of an active ECM system while the operator is performing render safe procedures on explosive hazards. The EOD technician will be provided status of EOD counter radio-controlled improvised explosive device electronic warfare (CREW) systems operating in his/her immediate periphery, eliminating uncertainty about whether the system is on and radiating (Kearney 2016). The objective of this technology development project is to, “provide a small radio frequency (RF) receiver device that provides the EOD operator a way to monitor the desired CREW system status to include faults, battery power, and detrimental variations in received RD energy" as the technician performs render safe procedures on various explosive hazards (Perry 2018). Following the MTAB's acceptance of the 2016 statement of need, the Commander, Naval Sea Systems Command PMS-408 CREW, accepted the requirement to develop the desired technology as a situational awareness tool.

The counter radio-controlled improvised explosive device electronic warfare situational awareness tool (CREW-SAT) program is a current, ongoing joint EOD technology development initiative utilizing the defense acquisition life cycle process (Perry 2018). Figure 26 outlines the first stages of the defense acquisition life cycle process. The CREW-SAT program is currently in the pre-materiel solution analysis (MSA) phase because the program has not met the material development decision criteria (Perry 2018). As part of the joint capabilities integration and development system (JCIDS) process, the MTAB recommended and received approval to conduct a market survey to determine the current state of technological maturity and availability to meet design requirements and to provide a basis for determining the technology readiness level of the CREW-SAT concept to inform the course of actions required for the acquisition of a material solution (Berrios 2019).

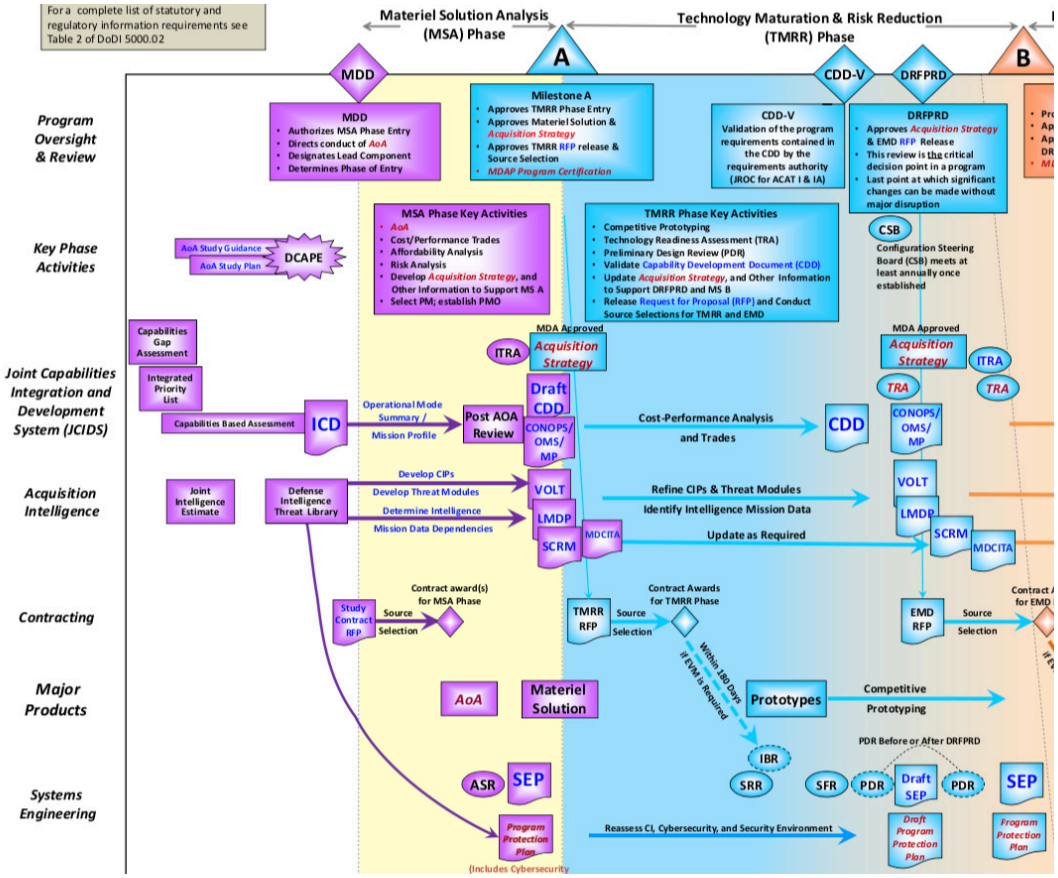


Figure 26. Defense Acquisition Life Cycle Compliance Baseline. Source: dau.mil (2019).

The market survey was conducted in October 2018 and concluded the realization of the CREW-SAT device was achievable, current technologies exist at the subsystem level, and the technologies are readily available (Bonilla 2018). The market survey was a critical component of the program development lifecycle to determine the feasibility of realizing the concept through a technology development materiel solution. Following the market survey report, NSWC IHEODTD determined commercial off the self (COTS) solutions were not able to receive and display status information of CREW hardware and simultaneously measure and assess fluctuations in RF levels (Berrios 2019). Although COTS RF detectors are readily available, reliable, and cost effective, the information provided to the EOD operator with respect to CREW systems is very limited. NSWC IHEODTD concluded the developmental path for realization of the material solution would be selected because the existing COTS solutions would not offer sufficiently reliable and valuable data to the EOD technician (Berrios 2019). The activities, research, and conclusions made by NSWC IHEODTD were all steps in the acquisition life cycle leading towards developing and procuring a material solution and the CREW-SAT program is progressing towards MSA phase as outlined in Figure 26.

E. SILENT SPRING PROGRAM

The silent spring program is an ongoing technology development initiative by NSWC IHEODTD and PMS-408 authorized in 2016 with a statement of need for desensitization and neutralization of explosives. In September 2016, the EOD program board concurred with the statement of need for desensitization and neutralization of explosives provided by the joint EOD MTAB (Martinez 2016). The joint EOD MTAB identified the need to desensitize and neutralize explosives to reduce the hazards they pose to personnel and property. "EOD technicians require the capability to safely mitigate the hazards associated with both commercial and homemade explosives (HME) in cases where they pose a threat to personnel and property…[and] are encountered in many forms including powders, granules, chunks, pastes, and slurries; which are all, to some varying degrees susceptible to detonation when subjected to heat, shock, and/or friction" (Martinez 2016). The statement of need identified EOD technicians required a substance that can be mixed quickly or is already in solution that will desensitize the explosives, so they may be safely transported to a disposal site or would neutralize the explosive, so it no longer presents an explosive hazard (Martinez 2016).

The requirement for a desensitization and neutralization of explosives capability was established and joint EOD MTAB and validated by the joint EOD program board as an urgent requirement to seek a streamlined development and transfer to the warfighter (G. Carroll, email to assistant program manager, March 25, 2019). The silent spring technology development initiative will result in a commercial product developed by the government and licensed utilizing a PLA with selected vendors to be available to joint EOD forces by national stock number (NSN) (G. Carroll, email to assistant program manager, March 25, 2019).

NSWC IHEODTD has developed the silent spring program utilizing the Navy / Marine Corp agile technology transfer process. The agile technology transfer process for Navy / Marine Corps programs is outlined in figure 27. The DoD RDT&E outlines seven budget activity codes. They are 6.1 utilized for basic research, 6.2 for applied research, 6.3 for advanced technology development, 6.4 applied towards advanced component development and prototypes, 6.5 used for system development and demonstration, 6.6 for RDT&E management support, and 6.7 for operational system development (Congressional Research Service 2018). As figure 27 outlines, 6.1, 6.2, and 6.3 RDT&E budget activity codes are utilized for science and technology programs. 6.4, 6.5, and 6.7 RDT&E budget activity codes are utilized for research and engineering programs.

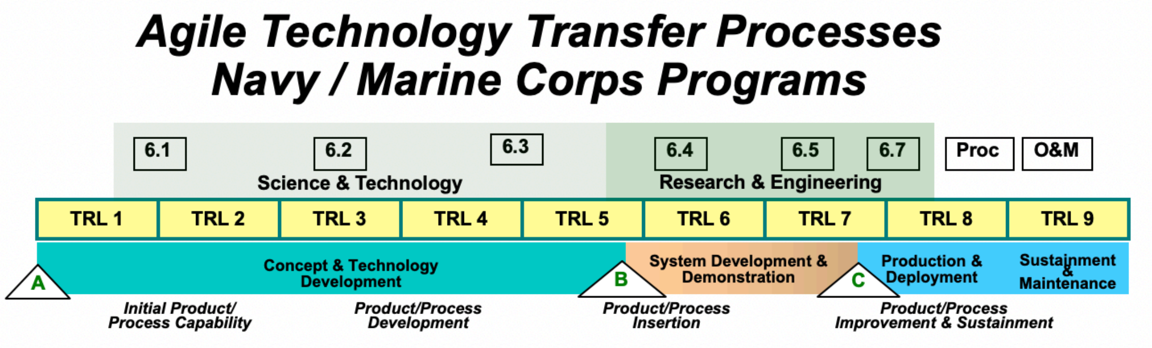


Figure 27. Navy/Marine Corps Programs Agile T2 Processes. Source: dau.mil (2019).

The silent spring program has been an accelerated technology transfer initiative through the partnership with civilian companies utilizing CRADA allowing for the preparation for manufacturing while still conducting research and testing. This was achieved through a combination of 6.3 advanced technology development and 6.4 advanced component development and prototypes DoD RDT&E budget activity codes (B. Milani, email to equipment specialist, June 5, 2019). The advanced technology development budget activity includes, “development of components into system prototypes for field experiments and result in proof of technological feasibility and assessment” (Congressional Research Service 2018). Projects in the 6.3 category “have a direct relevance to identified military needs” (Congressional Research Service 2018). The advanced component development and prototypes budget activity include "efforts necessary to evaluate integrated technologies, representative modes, or prototype systems in a realistic operating environment to help expedite technology transition from the laboratory to operational use" (Congressional Research Service 2018). Through these initiatives and efforts, the silent spring program was able to achieve the LRIP for OT&E in August 2019 with FRP expected in first quarter, fiscal year 2021 (C. Wilhelm, email to customer advocate for science and technology, July 18, 2019). Utilizing the CRADA and accelerated technology transfer initiatives, the silent spring program was able to reach the LRIP milestone for $1.735 million with another $200 thousand requested for OT&E (C. Wilhelm, email to customer advocate for science and technology, July 18, 2019).

F. CONCLUSIONS

The authors presented three NSWC IHEODTD technology development and transfer initiatives for comparison. The methods utilized for the three programs varied affecting the rate and cost at which the technology was developed and transferred. Table 1 summarizes the results of the three programs.

Table 1. Summary of NSWC IHEDOTD T2 Programs.

Program	Concept Proposed	Approved for Development (Authority)	T2 Methods	Time to LRIP	Cost
PAN	1998	1999 (PEO MINWAR)	-Abbreviated Acquisition Program -CRADA	5 years	Total: $3.7 MIL $2.35 MIL (RDT&E) $1.35 MIL (OPN)
CREW SAT	2012	2016 (Joint EOD MTAB)	-Defense Acquisition Life Cycle Process	Program has not achieved MSA	Costing Data Not Available for JCIDS phase
SILENT SPRING	2012	2016	-CRADA	3 years	Total: $2.115 MIL

The PAN program was proposed in 1998 and approved for development in 1999 by PEO MINEWAR. PEOMINWAR approved the PAN program for development as an abbreviated acquisition program and utilized CRADA. The PAN program achieved LRIP in five years with a total cost of $3.7 million. The CREW SAT program was proposed in

2012 and approved for development in 2016 by the Joint EOD MTAB. The CREW SAT program is ongoing and utilizing the defense acquisition life cycle process for development. The CREW SAT program has not achieved MSA. The Silent Spring program was proposed in 2012 and approved for development in 2016 by PMS-408, the Joint EOD MTAB, and a validated statement of need. The Silent Spring program is being developed utilizing CRADA and the Navy agile T2 process by combining DoD RDT&E budget activities 6.3 and 6.4. The Silent Spring program achieved LRIP in 3 years with a total cost of $2.115 million. The authors presented the three technology development programs to show the different methods available for T2 activities in the Navy. The authors have shown the T2 methods utilized for the Silent Spring program accelerated the development and transfer activities and saved money for the government as compared to the other methods shown. The T2 methods utilized for the Silent Spring program are not unique to the activities for this specific technology and can be replicated for future T2 programs.

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VII. SUMMARY AND CONCLUSIONS

A. SUMMARY

This thesis has used three case studies of actual DoD acquisition programs to demonstrate the benefit to both cost and schedule of the defense acquisition life-cycle when technology transfer activities are effectively employed by the DoD laboratory. Additionally, several methods for employing affordable and readily available systems engineering and systems architecture tools to aid in technology transfer have been described. These tools are well understood within most DoD laboratories, and are an effective way of increasing knowledge sharing, market knowledge, and marketing for the laboratory and patented DoD technologies. Lastly, a new product development process has been described that combines traditional technology transfer methods and the technical rigor of systems engineering.

Systems engineering and systems architecture can support technology transfer activities within DoD laboratories. When properly employed they can lower the risk realized by commercialization partners, as well as supporting economic growth. These tools will provide for improvements in the technology transfer mission, increase ROI, support initiatives started within the past two presidential administrations and provide for the best use of taxpayer dollars,

B. CONCLUSIONS

Although there exists an extensive body of literature that focuses on the different and difficult aspects of technology transfer activities, the majority of these works focus on an academic environment. Additionally, although there have been strong calls from the Office of the President over the past decade to improve efficiencies and ROI with technology transfer activities, very few practical tools and techniques have been identified. The authors believe that this body of work represents one of the few studies that ties the technical rigor of systems engineering to technology transfer activities. These tools and techniques are well understood within the federal laboratory system and can be employed with a minimum amount of effort.

Systems engineering and systems architecture models and viewpoints can employed by DoD laboratories to increase knowledge sharing and knowledge transfer with academic and industry partners. Models and viewpoints provide a simple means of communication while allowing for the removal of extraneous details. Models and viewpoints can also support technology marketing and facilitate a better understanding of the market space, user needs, and capability improvements.

Additionally, the technical rigor employed within the DoD acquisition process and the series of systems engineering technical reviews used to track progress can also be employed to provide technical rigor to technology transfer activities. The use of systems engineering technical reviews can support Souder, Nashar, and Padmanabhan stages of technology transfer; prospecting, developing, trial, adoption (1990); to be employed in a methodology that is similar to the stage and gate process presented by Cooper (1988). The stage and gate process has been employed as a new product development successfully for many decades, and been adapted to several other types of efforts (Cooper 1996; Jagoda, Maheshwari, and Lonseth 2010; Soenksen and Yazdi 2017; Grönlund, and Frishammar 2010).

Finally, the benefits that technology transfer activities can provide to a defense acquisition program have been made clear. Often times, dual-use technologies can benefit the most significantly, and the most directly, from technology transfer activities; but the majority of DoD programs can benefit in some way from T2. The cases presented in this thesis demonstrate significant cost and timeline reductions for programs that participated in technology transfer.

C. RECOMMENDATIONS

The DoD acquisition programs should participate and leverage technology transfer activities to the maximum extent possible. This provides for reduced acquisition times, allows for the leveraging of third-party funds, and provides the best use of taxpayers' dollars. The use of systems engineering and systems architecture tools and practices to support technology transfer activities provides for an inexpensive and convenient means to increase knowledge sharing and improve marketing during T2 activities. Additional systems engineering practices can provide for valuable decision gates during technology transfer activities as well.

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