2018-06

CASE STUDIES ON TECHNOLOGY ADOPTION IN NAVY ENERGY AND ENVIRONMENTAL TECHNOLOGY PROJECTS

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http://hdl.handle.net/10945/59668

NAVAL
POSTGRADUATE
SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL PROJECT

CASE STUDIES ON TECHNOLOGY ADOPTION IN NAVY ENERGY AND ENVIRONMENTAL TECHNOLOGY PROJECTS

June 2018

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REPORT DOCUMENTATION PAGE

Form Approved OMB
No. 0704-0188

1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** June 2018	**3. REPORT TYPE AND DATES COVERED** MBA Professional Project

4. TITLE AND SUBTITLE
CASE STUDIES ON TECHNOLOGY ADOPTION IN NAVY ENERGY AND ENVIRONMENTAL TECHNOLOGY PROJECTS

5. FUNDING NUMBERS

6. AUTHOR(S) Kristi L. Gordon

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release. Distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT (maximum 200 words)

Bridging the gap over “the valley of death” is the purpose of technology transition programs and is not a new challenge for the Navy. However, these initiatives usually focus on technology development, not on the adoption side of the transition gap. The Navy created the Adoption Readiness Level framework to assist transition managers with this challenge. This thesis compares the ARL framework to other popular frameworks found in literature and uses them to analyze five cases of energy and environmental technologies in order to draw conclusions regarding common barriers to technology adoption on Navy installations.

The research found that adoption was defined as the point when all associated technical specifications, codes, and standards were updated to reflect the new technology. It was generally assumed that decisions regarding technology adoption are made based on rational factors such as functional and economic advantage. However, cultural conflicts across various professional communities presented a significant challenge to achieving the level of acceptance needed to facilitate technology adoption. Factors that contributed to positive outcomes included understanding the culture of the professional communities that serve as critical change agents and targeting those groups through strategic communications. The ARL framework can be improved by more specifically addressing culture, the role of change agents, and the need for strategic communications at the earliest level.

14. SUBJECT TERMS
Adoption Readiness Levels, Technology Readiness Levels, TTP, professional communities of practice, Energy Cultures Framework, change agent, NESDI, ESTEP, ESTCP, TECHVAL, SBIR, energy, environmental, NAVFAC, EXWC, technology, innovation, technology adoption, technology transfer, technology transition

15. NUMBER OF PAGES
83

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
June 2018

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TABLE OF CONTENTS

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LIST OF FIGURES

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LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

ACAT	acquisition category
AFFF	aqueous film forming foam
ARL	adoption readiness level
ASN (RD&A)	Assistant Secretary of the Navy for Research, Development and Acquisition
CECOS	Civil Engineer Corps Officer School
COP	community of practice
COTS	commercial-off-the-shelf
DLA	Defense Logistics Agency
DOD	Department of Defense
DOE	Department of Energy
DHS	Department of Homeland Security
EPA	Environmental Protection Agency
eROI	energy return on investment
ESC	Engineering Service Center
ESPC	energy savings performance contract
ESTEP	Energy Systems Technology Evaluation Program
ESTCP	Environmental Sustainability Technology Certification Program
EXWC	Engineering and Expeditionary Warfare Center
FEMP	Federal Energy Management Program
GAO	Government Accountability Office
GSA	Government Services Administration
HVAC	heating, ventilation and air conditioning
JCTD	Joint Capability Technology Demonstration
MPI	Master Painter Institute
NAS	Naval Air Station
NAVFAC	Naval Facilities Engineering Command
NESDI	Navy Environmental Sustainability Development to Integration Program
NFPA	National Fire Protection Association

NPS	Naval Postgraduate School
NRC	National Research Council
O&M	operations & maintenance
ONR	Office of Naval Research
OSHA	Occupational Safety and Health Administration
PPEP	Pollution Prevention Equipment Program
PV	photovoltaic
RDT&E	research, development, testing and evaluation
SBIR	Small Business Innovation Research
S&T	science and technology
SIR	savings to investment ratio
SPAWAR	Space and Naval Warfare Systems Command
SPIDERS	Smart Power Infrastructure Demonstration for Energy Reliability and Security
SRM	sustainment, restoration and modernization
TARDEC	Tank and Automotive Research and Engineering Center
TECHVAL	technology validation
TRL	technology readiness level
TTP	technology transition program
UESC	utility energy service contract
UFC	unified facilities criteria
UFGS	unified facilities guide specifications
USACE-CERL	U.S. Army Corps of Engineers Construction Engineering Research Lab
VOC	volatile organic compound

ACKNOWLEDGMENTS

First, I would like to thank the following individuals at NAVFAC EXWC for giving me their time and knowledge about the cases contained herein: Mr. Kail Macias, Mr. Daniel Zarate, Mr. Andy Drucker, Mr. Paul Kistler, and Mr. Bill Anderson. I would also like to thank my advisors, Dr. Nick Dew and Dr. Eva Regnier, for pushing me to dig deep into the literature and apply it to the case studies. Finally, I would like to extend a special note of gratitude to my husband, Eric, and son, Gabriel, for supporting me while I worked many long nights and weekends on this project.

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I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to create and analyze case studies on technology adoption in Technology Transition Programs (TTP). More specifically, the research applies a qualitative approach to identifying and understanding common themes in the adoption of energy and environmental technologies on Navy installations. The work couples research on innovation with interviews of Science and Technology (S&T) professionals—herein referred to as "transition managers," regardless of their formal job title— to determine barriers to and support for technology adoption within these TTPs. The research also investigates the technology integration, stakeholder and process dimensions of the Navy's Adoption Readiness Level (ARL) framework to determine how ARLs may be used to improve technology adoption. The goal of this study is not to critique the transition process managers within the cases described nor is it to validate any of the various models found in the literature. Instead, the goal to aid program managers and other decision-makers to understand how much culture, psychology, and communication impact technology transition in order for them to more effectively facilitate adoption of technologies on Navy installations.

B. RESEARCH QUESTIONS

This thesis seeks to answer the following questions:

- What does "successful technology adoption" mean to S&T professionals?
- What barriers have prevented the adoption of technologies in TTPs?
- What factors contribute to successful adoption of technologies?
- How might ARLs aid or improve technology adoption at Navy installations?

C. BACKGROUND

1. Decision Points, Clearances and the Probability of Adoption

In their book, *Implementation: How Great Expectations in Washington are Dashed in Oakland,* Pressman and Wildavsky (1984) state:

> If one is always looking for unusual circumstances and dramatic events, he cannot appreciate how difficult it is to make the ordinary happen (p. xii)

They argue that the probability of successful implementation of any government program is very low and go on to say that "the remarkable thing is that new programs work at all" (1984, p. 109). Their research defines *decision points* as times within the execution of a program when an act of agreement is required for the program to continue and a *clearance* as a time when an individual must give consent for a program to continue (1984, p. xvi). Multiple clearances may be required at any given decision point. Pressman and Wildavsky believed that even "the apparently simple and straightforward is really complex and convoluted" (1984, pp. 91-92). Rogers concluded, similarly, that the "more persons involved in making an innovation-decision, the slower the rate of adoption" (2003, p. 21) and that "technology transfer is difficult…because we have underestimated just how much effort is required" (2003, p. 152). Understanding the challenges facing implementation of change within the government is critical to designing processes to overcome them.

The ARL framework is a tool to help transition managers to identify the decision points and clearances required to transition a technology from development to adoption. The idea is that each of these points could become a barrier to adoption. The more decision points and clearances required, the lower the probability that the technology will be adopted. This is important as the Navy, at the shore installation level in particular, has limited resources and the ARL framework can assist leaders with prioritizing and focusing their efforts on projects with a greater chance of adoption.

2. Definitions

A number of terms, while synonymous in common language, have nuanced meanings in the research literature and among the S&T community. It is important to define these terms as they are used in this study. Govindarajan (2012) defines *innovation* as "any project that is new to you and has an uncertain outcome" (p. 5). Hage and Meeus (2009) define *incremental innovations* as improvements in existing technologies and systems and *radical innovations* as new architecture or technological approaches (p. 26). Rogers (2003) defines *diffusion* as "the process in which an innovation is communicated through certain channels over time among the members of a social system" (p. 5). The technologies discussed within this study are considered innovations, and can be classified as either incremental or radical.

Several terms that are sometimes used interchangeably are *implementation*, *transition, transfer, diffusion* and *adoption*. Pressman and Wildavsky (1984) state that the term *implementation* means "to carry out, accomplish, fulfill, produce, complete" (p. xiii). This is a broad definition that could include both *transition* and *adoption*. However, the terms *transition* and *adoption* are not necessarily synonymous.

In a 2013 report on TTPs, the Government Accountability Office (GAO) acknowledged that the term *transition* had different meanings, depending on the audience, and used the term to encompass the following situations: transition to an acquisition program, transition directly to the warfighter in the field, or transition to other users such as private industry or another development program (Government Accountability Office [GAO], 2013). Rogers' (2003) explanation of three levels of technology *transfer* is very similar to the GAO's description of transition: the first level is that the user knows about the technology, the second level occurs when the technology is in use within an organization, and the third is when the technology has been commercialized.

Defining *adoption* is more challenging. Rogers (2003) defines adoption as "a decision to make full use of an innovation as the best course of action available" (p. 21). For some of the TTP projects studied within this research, adoption occurred when applicable codes and specifications were updated to incorporate the technology, regardless of the rate of technology use or installation. For other projects, the technology was not considered adopted until it was in operational use at multiple locations or by multiple end users throughout the Navy. Both of these examples meet the definition provided by Rogers but present very different scenarios to the transition managers. Therefore, more clearly defining the term *adoption* in the context of technologies on Navy installations is one of the goals of this study.

3. Technology Transition Initiatives

Technology transition from development to adoption is not new to the Department of Defense (DOD) or to the Navy. Bridging the gap over “the valley of death”—the transition from innovation to acquisition, as it is commonly known in the literature—is an ongoing challenge and no single method or framework has proven sufficient to tackle it (National Research Council of the National Academies [NRC], 2004). The DOD has supported a number of initiatives aimed at improving technology transition to the warfighter.

Technology transition initiatives usually focus on technology development, not on the technology adoption side of the transition gap. The goal of these initiatives is to ensure that technologies are appropriately mature before pushing or pulling them into the acquisition system. A 2013 GAO report highlighted two reasons for technology transition failure: either the technology was not mature enough or the acquisition system and processes were insufficient to expedite transition of appropriately mature technology. The report also identified that few transition programs tracked and measured adoption outcomes; that is, whether the technology was fully adopted and resulted in a benefit to the user (GAO, 2013).

The DOD follows the Acquisition System Framework to develop major systems. This framework is a linear stage-gate model that utilizes Technology Readiness Levels (TRL) to assess the technology’s maturity and facilitate decision making about its adoption (Assistant Secretary of Defense for Research and Engineering [ASD(R&E)], 2011). TRLs are defined in Table 1.

Table 1. Department of Defense Technology Readiness Levels. Adapted from ASD(R&E) (2011).

TRL	Definition	Description
1	Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.
2	Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4	Component and/or breadboard validation in a laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5	Component and/or breadboard validation in a relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components.
6	System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.
7	System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an air-craft, in a vehicle, or in space).
8	Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to deter-mine if it meets design specifications.
9	Actual system- proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.

A technology may be fully mature at a TRL 8 or 9, but fail to be adopted. This may happen on a Navy installation for many reasons: a commercial product could fail to meet Buy America Act (Federal Acquisition Regulation [FAR], 2018) requirements and require a waiver; a system or component may create cybersecurity vulnerabilities that render them unusable; or the operations and maintenance of the technology requires specialized training and funding that was not programmed appropriately, to name a few examples. The transition from innovator to user is anything but seamless, and many stakeholders must be considered and involved throughout the process.

In this research, several programs are discussed and the process used within the programs to facilitate adoption of selected projects is explored. These programs are detailed in Table 2. Each program has the goal of technology transition by either developing and/or demonstrating and validating a technology that is designed to address a specific energy or environmental challenge impacting Navy facilities. Some, particularly the research, development, testing and experimental (RDT&E) funded programs, are more focused on the technology development side of the valley of death while others, particularly those that are operations and maintenance (O&M) funded, are more focused on the acquisition side because the technologies are already well-developed or commercially available.

Table 2. Summary of Some Technology Transition Programs Used within the Navy

Program	Sponsor	Funding Type	Description
SBIR	SBA/DOD	RDT&E	The Small Business Innovation Research program is a federal program, managed by the Small Business Administration, with execution authority granted to various federal agencies. Within DOD, the program is RDT&E funded to increase the participation of small businesses in the research and development of innovative technologies (DOD Small Business Innovation Research Program "About", 2018).
ESTEP	Navy	RDT&E	In 2013, the Office of Naval Research established the the Energy Systems Technology Evaluation Program which is a partnership between NPS, NAVFAC, and SPAWAR that demonstrates advanced energy technologies on Navy and Marine Corps installations (Adams, 2017).
ESTCP	DOD	RDT&E	Established in 1995, the Environmental Security Technology Certification Program is a DOD environmental technology demonstration and validation program that identifies and demonstrates promising environmental technologies likely to provide cost-effective solutions for environmental problems impacting military operations and facilities (About ESTCP, 2018).
JCTD	DOD	RDT&E	DOD established the Joint Capability Technology Demonstration program originally in 1996 as the Advanced Concept Technology Demonstration Program. The program develops and demonstrates prototype technologies that directly address joint and combatant command warfighter needs and facilitates affordable transition of the technologies to the acquisition community (Joint Capability Technology Demonstration Program Overview, 2018).
NESDI	Navy	RDT&E	The Navy Environmental Sustainability Development to Integration Program is an environmental demonstration and validation program targeteting solutions to shoreside environmental problems and is managed by the NAVFAC EXWC (About NESDI, 2018).
PPEP	Navy	O&M	The Navy's Pollution Prevention Equipment Program for the purchase of commercial off-the-shelf (COTS) products for pollution prevention. (A. Drucker, interview with author, February 6, 2018).
TECHVAL	Navy	Geothermal[1]	The Navy's Technology Validation program, managed by the NAVFAC EXWC, to demonstrate COTS products and validate their performance in naval facilities (NAVFAC, Navy Techval, 2018). The program began in 2003 and was unfunded in 2015 (P. Kistler, email to author, February 27, 2018).

[1] The Geothermal Program Office, under NAVFAC EXWC, oversees geothermal power plants operating on Navy lands. Royalty revenues from the sale of power generated at these plants have been used to fund various projects. Source: (GAO, 2004).

D. ORGANIZATION AND METHODOLOGY

This study is laid out in six chapters. The first chapter introduces the research and provides background information on technology transition programs used within the DOD and Navy, and lays out the organization of the study. Chapter II provides a review of existing literature related to innovation research and barriers to technology adoption, and ties the ARL framework to that literature. Chapter III presents case studies of energy and environmental technology projects. Chapter IV presents a qualitative analysis of the case studies and Chapter V provides final conclusions and recommendations.

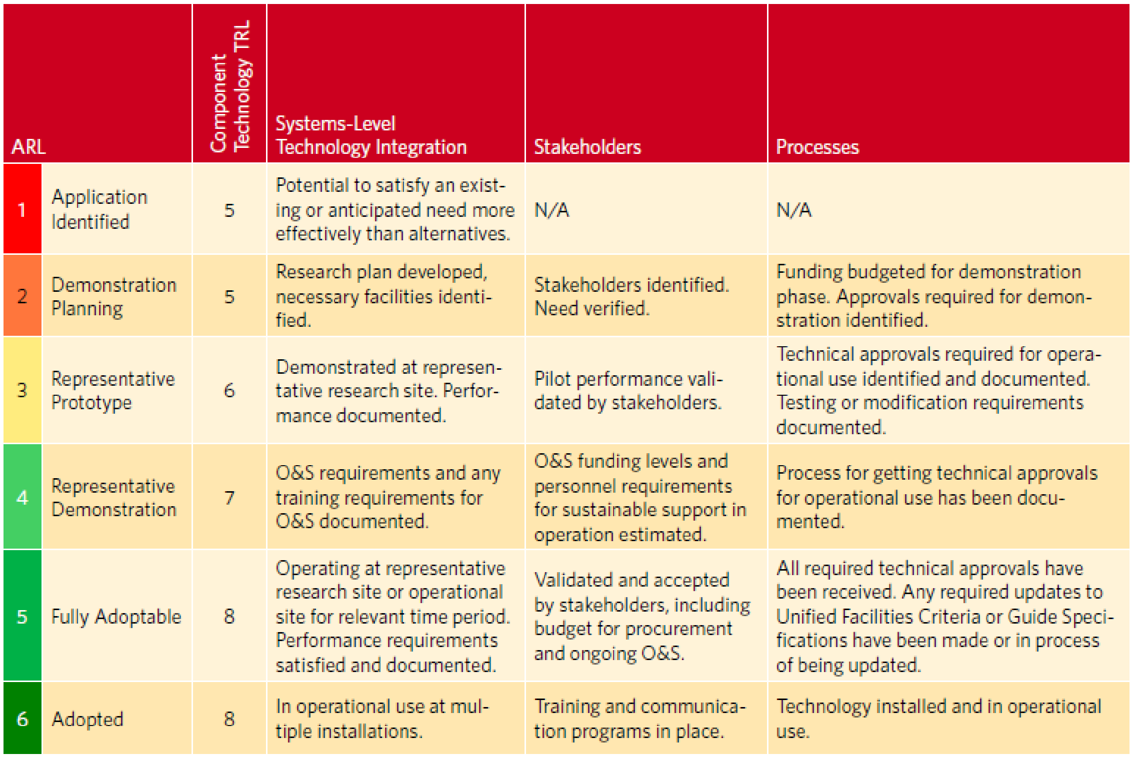
This research takes a multi-case study approach. The unit of analysis used is a case study on a demonstration project written based on interviews with transition managers at the Naval Facilities Engineering Command (NAVFAC) Engineering and Expeditionary Warfare Center (EXWC) in Port Hueneme, California. The EXWC Technical Director identified four subject matter experts (SME) across various technology transition programs for interviews. Standardized interview questions were emailed to the SMEs in advance of the interviews. The SMEs identified projects for discussion and presented them to the author during interviews conducted at EXWC on February 6–7, 2018. Case studies were written based on selected energy and environmental technology projects demonstrated on military installations that highlighted the challenges of transitioning technologies that were adopted and those that failed to be adopted. The strategy of the case analysis is the application of theoretical propositions with rival explanations. The technique used is pattern-matching with cross-case synthesis (Yin, 2009). The various theoretical models and frameworks explored during the literature review were applied to each case to identify common themes that might explain the adoption outcomes.

II. LITERATURE REVIEW

The innovation literature is vast and this review is not exhaustive. Instead, this research focuses on a few frameworks that may best apply to energy and environmental technologies. The purpose of this literature review is to establish a connection between the ARL framework and existing research literature. This chapter begins with an introduction to the ARL framework. Each subsequent section examines a different model—Rogers' Five Factors, the Energy Cultures framework, Professional Communities of Practice (COP), and the Garbage Can Model in public policy—and compares it to the ARL framework.

A. WHAT IS THE ARL FRAMEWORK?

As part of the Energy Systems Technology Evaluation Program (ESTEP), researchers at the Naval Postgraduate School (NPS), along with NAVFAC and the Space and Naval Warfare Systems Command (SPAWAR), created the ARL framework in 2015 to aid adoption of technologies at Navy shore installations (Regnier, Barron, Nussbaum, & Macias, 2017). The ARL framework is shown in Figure 1. While technology readiness is an important component of the framework, the ARL also targets the acquisition side of the "valley of death" by focusing on the integration of the technology, stakeholders and processes beyond the maturing of the technology. However, its recent development means there is limited research into its use or effectiveness. Also, since most TTPs do not track the adoption of technologies beyond their transition to the acquisition community (GAO, 2013), it is difficult to measure effectiveness of ARLs or any other TTP process.



ARL		Component Technology TRL	Systems-Level Technology Integration	Stakeholders	Processes
1	Application Identified	5	Potential to satisfy an existing or anticipated need more effectively than alternatives.	N/A	N/A
2	Demonstration Planning	5	Research plan developed, necessary facilities identified.	Stakeholders identified. Need verified.	Funding budgeted for demonstration phase. Approvals required for demonstration identified.
3	Representative Prototype	6	Demonstrated at representative research site. Performance documented.	Pilot performance validated by stakeholders.	Technical approvals required for operational use identified and documented. Testing or modification requirements documented.
4	Representative Demonstration	7	O&S requirements and any training requirements for O&S documented.	O&S funding levels and personnel requirements for sustainable support in operation estimated.	Process for getting technical approvals for operational use has been documented.
5	Fully Adoptable	8	Operating at representative research site or operational site for relevant time period. Performance requirements satisfied and documented.	Validated and accepted by stakeholders, including budget for procurement and ongoing O&S.	All required technical approvals have been received. Any required updates to Unified Facilities Criteria or Guide Specifications have been made or in process of being updated.
6	Adopted	8	In operational use at multiple installations.	Training and communication programs in place.	Technology installed and in operational use.

Figure 1. Adoption Readiness Levels. Source: Regnier et al. (2017).

Stakeholder engagement during technology development appears to be a critical piece to the transition and adoption puzzle. Even in their early research, Pressman and Wildavsky address the need to coordinate with stakeholders and warned against bypassing bureaucratic processes (Pressman & Wildavsky, 1984). Sovacool et al. indicate that consumers may resist change due to a lack of trust of the system because they were not incorporated into its design (Sovacool, Kivimaa, Hielscher, & Jenkins, 2017). They describe consumers as emotional actors, not rational followers, who should be engaged and allowed to provide feedback during technology development and transition (Sovacool et al., 2017). Mathieson also argued that user participation was key to technology acceptance (Mathieson, 1991). The National Research Council (NRC) concluded that collaboration among stakeholders drives technology development and adoption and that TTPs must include stakeholders (NRC, 2004). Two of their recommended best practices were to create a multidisciplinary team and to focus on function rather than specifications in order to accelerate technology transitions within TTPs (NRC, 2004). The ARL framework addresses stakeholders specifically as a dimension within it, recognizing the importance of early identification and engagement throughout the various levels of transition.

B. ROGERS' FIVE FACTORS

1. Introduction to the Model

Rogers' (2003) research determined that "49 to 87 percent of the variance in the rate of technology adoption is explained by five perceived attributes of the innovation: relative advantage, compatibility, complexity, trialability, and observability" (p. 221). Relative advantage is the perceived benefit of the technology over that which precedes it and can be economic, social or functional (Rogers, 2003). Compatibility describes the consistency "with the existing values, past experiences, and needs of potential adopters" (Rogers, 2003, p. 240). Complexity explains the perceived difficulty of use and understanding of the technology, and trialability is the extent that a technology can be demonstrated to users (Rogers, 2003). Observability is explained as how visible the adoption of the technology is to other potential users (Rogers, 2003).

While product-focused innovation research is limited, other researchers have come to similar conclusions as Rogers. In their review of the Technology Acceptance Model, Chen, Li and Li (2011) declared that two determinants of technology acceptance were "perceived ease of use" (p.124), or complexity, and "perceived usefulness" (p.124), or relative advantage. Park, Kim, and Yong (2017), in their study of smart grid technology, determined that trial by consumers improves acceptance and addresses issues associated with compatibility, ease of use and risk management. In their study of energy behavior in the Marine Corps, Salem and Gallenson (2014) determined that energy technology adoption was dependent on the functionality, reliability, ease of use and desirability of the technology. These findings indicate the importance of the perceived attributes of the technology product to its adoption and are summarized in Table 3.

Table 3. Summary of Product-Based Determinants of Technology Acceptance

Rogers' Five Factors	Relative Advantage	Compatibility	Complexity	Trialability	Observability
Technology Acceptance Model (Chen, et. al)	Usefulness		Ease of Use		
Energy Behavior in USMC (Salem, et. al)	Functionality	Reliability	Ease of Use		Desirability
Adoption of Smart Grid Technology (Park, et. al)		Compatibility		Trialability	

2. How Does the ARL Framework Relate?

The systems-level technology integration dimension of the ARL framework addresses some of the product factors described by Rogers. ARL 1 targets the relative advantage factor by identifying that the technology is at least potentially more effective than other alternatives. ARL 3 targets compatibility as a prototype is tested and performance issues are addressed. ARL 4 targets the trialability factor as the technology is demonstrated for use. ARLs 5 and 6 address the observability factor because the more widely used the technology becomes, the more its use is propagated. However, the ARL framework does not directly address the complexity factor although it does specify documentation of training requirements and development of training programs which may be used to overcome complexity issues.

C. ENERGY CULTURES FRAMEWORK

1. Introduction to the Model

The researchers who developed the Energy Cultures framework recognized that “distinctive cultures of knowledge, belief, behaviour and material objects” impacted energy use (Stephenson et al., 2010, p. 6123). The framework, shown in Figure 2, presents an interactive system with a core made of three components: material culture, energy practices and cognitive norms (Stephenson et al., 2010). Physical and performance characteristics of the technology itself make up the material culture component. Energy practices are determined—and determine—the relationships “between individual, social and institutional behaviours” (Stephenson et al., 2010, p. 6124). The system of attitudes, values and beliefs within the individual or organization make up the cognitive norms (Stephenson et al., 2010). In addition, there is an outer ring of influences that impact and are impacted by the core components. Together, these components can explain outcomes in individual and organizational energy behavior.

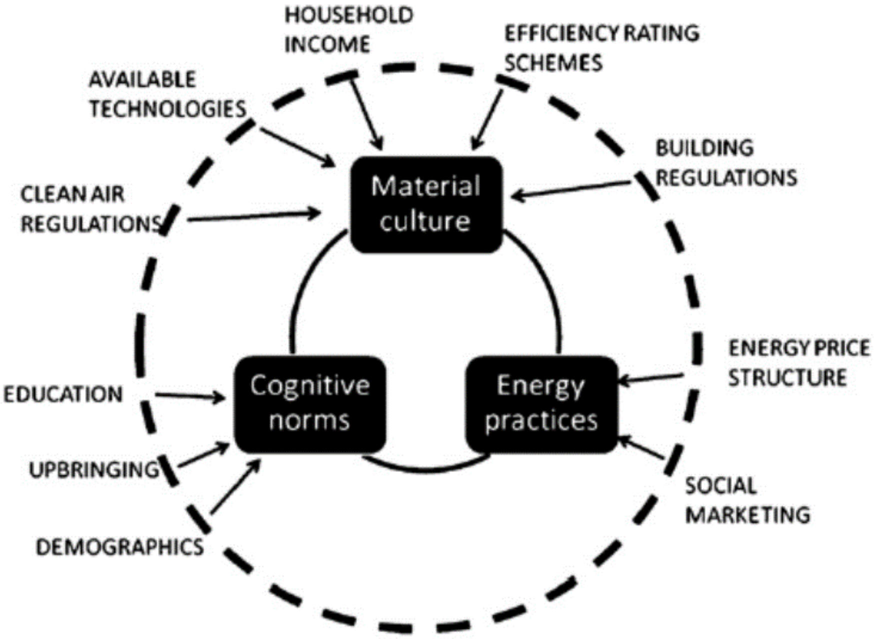


Figure 2. Energy Cultures Framework with Examples of Wider Influences.
Source: Stephenson et al. (2010).

Stephenson et al. argue that because the components are self-reinforcing, energy behavior stabilizes and the potential for change is minimized when the components are aligned. Change occurs when one or more of the components is misaligned (Stephenson et al., 2010). The Energy Cultures framework is not a deterministic model but instead helps to understand and consider the various factors that may impact behaviors. It is intended to be scalable for application at the individual through the national policy level (Stephenson et al., 2010).

Culture, both individual and organizational, can greatly influence technology adoption. Ram and Sheth’s (1989) research into consumer resistance to innovations identified two key categories of barriers: psychological and functional. Other research has targeted the lack of stakeholder engagement as a barrier to adoption. Innovations “may conflict with their consumers’ prior belief structure” (Ram & Sheth, 1989, p. 6).

Psychological barriers categorize resistance associated with cultural norms and perceptions about a product (Ram & Sheth, 1989). The authors imply that the greater a technology deviates from established traditions, the greater the resistance to its use (Ram & Sheth, 1989). The NRC (2004) recognized that successful technology adoption was directly related to the culture of the organization as it depends “more on social, cultural and historical factors than on technological merit” (p. 9). Saukkonen et al. (2017) state “more research is needed on the interaction of personal and shared organizational values and their role in triggering energy-related investments” (p. 59). They argue that an organization’s investment decisions may not be limited to the optimal economic solution but instead is influenced by other decision-making criteria such as cultural considerations and how the technology fits into existing processes. The Energy Cultures framework addresses this research gap by establishing a relationship between the concepts of material culture, cognitive norms and energy practices.

2. How Does the ARL Framework Relate?

While the ARL framework does not specifically address culture, this aspect is embedded in the stakeholder dimension and may have an influence on the approvals requirement of the process dimension at each level. However, the ARL framework leaves the transition manager responsible for identifying those stakeholders and they may not fully understand the culture of the organization or competing roles of professionals within the various stakeholder communities. Understanding the culture and relationships between professionals in an organization is important for transition managers so that they can effect a shift in one or more of the core Energy Cultures framework concepts.

D. PROFESSIONAL COMMUNITIES OF PRACTICE

1. Introduction to the Model

In their research on professional communities in the healthcare industry, Ferlie et al. (2005) argue that “strong boundaries between professional groups at the micro level of practice slow innovation speed” and that “complex organizations contain many different professional groups, each of which may operate in a distinct community of practice” (p. 117). The concept of professional communities of practice focuses on the “underpinning social and cognitive boundaries that membership of a profession creates in relation to other professions” (Ferlie, Fitzgerald, Wood, & Hawkins, 2005, p. 117). Innovation often takes place within these large, multi-professional communities but the researchers discovered that the knowledge boundary between research and clinical practice was an important factor in the adoption of process changes noting that “knowledge diffuses within communities of practice” (Ferlie et al., 2005, p. 129) but has difficulty crossing the boundaries between those communities. According to Thomas Allen (1977), in his research on technology transfer within R&D organizations, the different views and language used by individuals and within organizations creates “an inherent problem whenever communications must take place across an organizational boundary” (p. 139).

Hekman et al. argued that a boundary exists between professionals and administrators, even when the same administrators had professional training and experience (Hekman, Steensma, Bigley, & Hereford, 2009). Hekman et al. made a clear distinction between organizational identification and professional identification. Individuals who identified more closely with the organization tended to perceive administrators as like them and were more responsive to administrator-led change. However, individuals who identified more with their profession tended to perceive administrators as outsiders who are more concerned with profitability than with quality (Hekman et al., 2009). These boundaries and multidisciplinary organizations present barriers to technology adoption.

The next question is: how can communication and dissemination of knowledge across these boundaries be fostered? Ferlie et al. (2005) argued that “such differences can only be overcome through social interaction, trust, and motivation” (p. 131). Allen (1977) introduced the term “technological gatekeeper” (p. 161) to describe an individual within an R&D organization who functioned as a “star” or “opinion leader” (p. 161) and was largely responsible for control and dissemination of information, both internally and externally. Other research has used terms such as champion, promoter and change agent to describe various roles of individuals who successfully implement innovative change (Plieth, Habicht, & Möslein, 2013). In their effort to understand who change agents are and how they succeed, Plieth et al. (2013) argue that these agents exist on four levels and examine how they are engaged at each phase of the innovation process. A summary of their research on the change agents and levels are shown in Table 4 and their incorporation into the innovation process is shown in Figure 3.

Table 4. Summary of Change Agent Levels, Roles and Functions. Source: Plieth et al. (2013)

Strategic Management Level	**Operational Management Level**	**Advisory Level**		**Community Level**
Top Management	**Middle Management**	**Internal Advisors**	**External Advisors**	**Innovation Community Members**
• Decision about (financial) resources • Envision the change	• Provision of freedom • Display of an exemplary change orientation	• Ability to support others in carrying an idea forward • Process skills to facilitate change • Expertise and network to facilitate change	• Moderation of the innovation process	• Push or challenge ideas • Personal networks

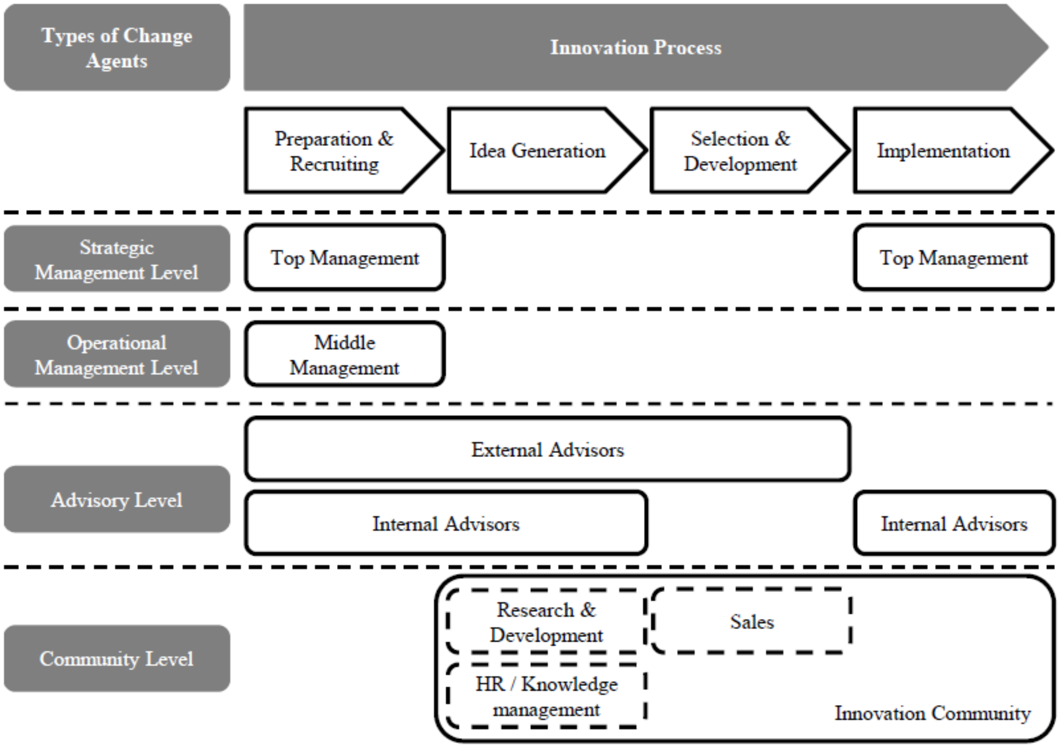


Figure 3. Change Agents in the Innovation Process. Source: Plieth et al. (2013).

The way an organization is structured and the influence of leadership to advocate for or resist innovation may also have a significant impact on technology adoption. Nahavandi's (1999) work supports this concept as stated in research on organizational behavior: "resistance to change is both an individual and organizational issue" (p. 501). Within the military, one of the greatest challenges is "overcoming cultural traits that are associated with hierarchical and rule-bound organizations and that impede technology transition" (NRC, 2004, p. 2).

Ram and Sheth's (1989) classification of functional barriers address usage, value and risk associated with an innovation. Examples of these types of barriers include organizational policies that prohibit use of a certain type of technology (usage) or that require a minimum economic return on investment (value). The authors imply that consumers are inherently risk-averse, so a technology that is perceived to have high physical, economic or social risk may not be adopted (Ram & Sheth, 1989). The NRC found that technology transition success stories within private industries indicated commonalities such as risk-tolerant and flat organizational structures (NRC, 2004).

The International Military Leadership Association Working Group, in their publication on technology and leadership, acknowledge that "organizational structures, routines and capabilities are needed to support both the emergence and implementation of innovative technologies" (Augier & Guo, 2017, p. 128). Interestingly, they also acknowledge that "military organizations have undergone some of the most disruptive transformations" (Augier & Guo, 2017, p. 130), despite their reputation for resistance. So, within the military there is the capacity for technology adoption but organizations struggle for a number of reasons. Govindarajan and Trimble (2012) summarize this struggle best in their statement that "organizations are not designed for innovation…they are designed for ongoing operations" (p. 10) and these are, therefore, "always and inevitably in conflict" (p. 11). This research supports the argument within the communities of practice literature regarding the conflicts between professionals and administrators.

2. How Does the ARL Framework Relate?

The Navy is a hierarchical organization made up of a number of professional communities of practice—from the various warfare communities to the systems and type commands. Within each of these communities of practice there are still more specialized professionals. The ARL framework addresses the influence of organizational structure within the process dimension. At each level, the framework targets required technical, funding and stakeholder approvals that are necessary to transition to the next level. However, the communication program is not considered until ARL 6. This is a very important component of the transition plan and should include consideration for how to educate professionals outside of the research community—end users, acquisition team members, industry professionals, and administrators—of the technology's value. It is too easy to assume that the technology demonstration will speak for itself. In order to successfully disseminate knowledge of the technology to stakeholders, it is important that the transition manager understand what the knowledge boundaries are for the various communities, identify the gatekeepers or change agents (Plieth et al., 2013), develop a communication plan and incorporate these things into the project at the appropriate phase of the innovation process. This is particularly important as the complexity of the technology increases because such complexity makes crossing the knowledge boundaries between professional groups even more challenging.

E. GARBAGE CAN MODEL

1. Introduction to the Model

In his research on public policy, Kingdon (2003) argues that policymaking does not follow a stage-like rational model. Instead, he expands on the "garbage can model of organizational choice" developed by Cohen, March and Olsen (1972) to explain the system through which agendas are set and policies are made (Kingdon, 2003). In Kingdon's (2003) model, there are three largely independent streams that flow into the garbage can: problems, policies and politics. A problem could be created from a "focusing event" (Kingdon, 2003) or could be a situation that has garnered enough attention to raise concern from a portion of a population. A policy is a proposed solution, but may not be dedicated to any given problem. For example, in the research world, a pet project could focus on developing a solution for a situation that may not yet have risen to the level of a problem or it could address multiple problems. Politics largely refers to the appetite of decision-makers to take action on a given issue or policy. A “policy window” opens for only a short period of time during which the problem, policy solution and political support must align in order for change to occur (Kingdon, 2003). A problem and policy solution could both exist within the garbage can but without the political appetite to take action, none will occur. Or, various policy alternatives could exist for a problem and a political decision could be made for one despite the rational benefits of another. This “coupling” of the three streams can be aided by a policy entrepreneur who advocates for a particular policy solution (Kingdon, 2003). Despite its seemingly random design, it is important to note that Kingdon argues that the garbage can model is not without structure.

2. How Does the ARL Framework Relate?

The ARL framework is a much more linear, rational model than the garbage can model. The framework begins with the assumption that a need or problem has been identified and a technology solution is adopted as one moves through the framework meeting the criteria outlined in each of the three dimensions: technology integration, stakeholders and processes. It also inherently assumes that a failure to move from one level to the next can be described by a rational decision not to adopt the technology because of a performance issue, inadequate funding or a lack of technical approval. However, the underlying cause of the decision to reject a specific technology may not be a rational decision at all. It is possible that a technology could meet all of the technical performance requirements and be a cost-effective solution but the real reason that it does not receive the necessary funding and approvals is because the issue it addresses is not perceived as a problem at a higher level. Or, when considering the political stream, there may be lobbyists or other players whose interests would be better served by a different alternative or the status quo. The transition manager in a TTP would likely act as a policy entrepreneur, moving the technology through the framework and to adoption, but would have to understand the political factors at play in order to improve the chance of success.

The ARL framework does address the need to identify and budget funding for the demonstration project and procurement of the validated technology for follow-on implementation. This is important as Kingdon (2003) specifically mentions the constraining influence of budgets. Competition for funding in fiscally constrained environments can certainly limit to the speed at which coupling occurs and can result in a technology being pushed aside until it is obsolete. Overall, the ARL framework and Garbage Can Model do not align well and it is difficult to make comparisons between the two with regard to explaining technology adoption.

F. CONCLUSION

The ARL framework was compared to four models found in the literature: Rogers' Five Factors, Energy Cultures framework, Professional Communities of Practice and the Garbage Can Model. A summary of this comparison can be found in Table 5. The systems-level technology integration dimension of the ARL framework was very good at addressing the product-focused characteristics of Rogers' Five Factors. However, it did not directly address the issue of complexity. The concept of material culture in the Energy Cultures framework was addressed by the systems-level technology integration dimension of the ARL framework. The concept of the influence of cognitive norms and energy practices are not explicitly addressed by the ARL framework but are embedded in the stakeholder and process dimensions. The process dimension of the ARL framework addresses the influence of organizational structure discussed within the professional communities of practice literature. However, change agents are key players in the COP literature and their involvement at different levels throughout the innovation process is critical to adoption. The concept of stakeholder identification, validation and acceptance is really very vague in the ARL framework and does not go far enough to enable transition managers to identify who the change agents are and focus their communication plan to those agents. The ARL framework, as a linear rational model, did not align well with the Garbage Can model because it focuses on developing a specific technological solution to a known problem. The Garbage Can model argues that problems, policies and politics are largely independent and come together in a policy window that allows for change to occur.

Table 5. Comparison of how ARL Framework Relates to the Other Models

	ARL Relation		
	Strong	Moderate	Weak
Rogers' Five Factors			
Relative Advantage	X		
Compatibility	X		
Complexity		X	
Trialability	X		
Observability	X		
Energy Cultures Framework			
Material Culture	X		
Cognitive Norms		X	
Energy Practices			X
Communities of Practice			
Strategic			X
Operational		X	
Advisory			
- Internal		X	
- External		X	
Innovation Community	X		
Garbage Can Model			
Problems	X		
Policies	X		
Politics			X

Many hurdles within the acquisition process can kill technology adoption. The literature indicates that most TTPs within the DOD focus on correcting technical issues and improving technology development. The GAO (2013) reported that “programs do not track their projects beyond transition, which limits their ability to know and report final outcomes for transitioned technologies and any associated benefits DOD achieved from those technologies” (p. 16). It is important to have an effective means to foster this transition to adoption.

In the case of Navy shore installations, a technology may be fully adoptable—in other words, equivalent to a TRL 7, 8, or 9—but not adopted because the end users, facility managers, contracting officers and other installation team members are not engaged during the development of the technology. Or, a technology may not be aligned with the organizational culture or existing structure. The Navy has recognized this gap and developed the ARL framework to improve the transition process and increase the rates of technology adoption. The ARL framework targets the acquisition side of the “valley of death.” The idea is that ALL stakeholders must be engaged in the technology development and transition process from a very early stage in order to identify technical compatibility, cultural, regulatory, and justification barriers. The ARL framework also aids decision makers to focus their limited resources on those technologies that show the highest probability of being adopted in order to balance the need for innovative solutions to technical problems with ongoing operations.

III. CASE STUDIES

A. NESDI PROJECT: NOFOAM SYSTEM FOR AUTOMOTIVE FIRE APPARATUS VEHICLE FOAM DISCHARGE CHECKS

1. Project Background

In 2005, the NESDI program developed the NoFoam System for Automotive Fire Apparatus to address environmental concerns with the discharge of aqueous film forming foam (AFFF) during routine system checks of automotive fire apparatus vehicles onboard Navy installations (Kudo, 2010). AFFF is used on fire apparatus vehicles to "rapidly extinguish flammable liquid and combustible liquid fires" (Kudo, 2010, p. 1). Navy policy requires annual checks of these systems in accordance with National Fire Protection Association (NFPA) codes to ensure the system is operable and performing properly. However, AFFF is considered toxic and has been listed as a hazardous air pollutant by the U.S. Environmental Protection Agency (EPA) (Kudo, 2010). Therefore, AFFF discharged during training and system checks must be treated as hazardous waste. Proper capture and disposal of AFFF proved to be cost prohibitive to the limited operational budgets at Navy installations and fire chiefs were forgoing the required system checks and training exercises (Kudo, 2010), resulting in increased risk to fire safety on these bases.

The NoFoam System for Automotive Fire Apparatus was developed by NAVFAC as a self-contained mobile unit that connects to the vehicles and bypasses the on-board AFFF system to discharge water in order to perform operational checks on the system. One NoFoam system can be used on multiple vehicles once the vehicles have been properly retrofitted for the bypass. The system was successfully demonstrated at three locations: Naval Air Station (NAS) Whidbey Island in 2006, NAS Jacksonville in 2007, and NAS Lemoore in 2008 (Kudo, 2010). The final demonstration project report was published by NAVFAC in 2010. Since that time it has been adopted for use by more than 200 fire apparatus vehicles DOD-wide (A. Drucker, interview with author, February 6, 2018).

2. Transition Process

The NoFoam System for Automotive Fire Apparatus was developed under NESDI and transitioned for DOD and commercial use via a license agreement to a private vendor. It is a proprietary system of the U.S. Navy and is available DOD-wide through the Defense Logistics Agency (DLA) and for public use through the licensee (A. Drucker, interview with author, February 6, 2018).

One of the first barriers to adoption of the NoFoam System for Automotive Fire Apparatus was the purchase cost. The economic analysis performed on the system at the time of development implied that the system would provide significant cost savings to the Navy and minimize risks associated with potential discharge of hazardous materials into the environment. The prototype was estimated to cost $25,000 for three vehicles and included the skid-mounted tank, retrofit kits, installation, testing and training (Kudo, 2010). Based on estimated costs of collection and disposal of AFFF, the system has a payback of two to five years assuming a minimum of one annual check per vehicle per year. Other alternatives include construction of an AFFF testing facility at each Navy installation estimated at a cost of $1 million per facility (Kudo, 2010). Despite the demonstrated environmental and economic benefits, the cost of the system was still prohibitive to rapid adoption at Navy installations. Purchase of the system would require programming through the budgeting process. Faced with tradeoffs due to limited budgets, installation commanders often prioritized the purchase of new or additional fire and rescue vehicles to update their aging fleet over the purchase of the NoFoam System (A. Drucker, interview with author, February 6, 2018). In order to overcome the cost barrier, NAVFAC was able to utilize the Navy’s Pollution Prevention Equipment Program (PPEP) to fund purchase of the system at various Navy installations (A. Drucker, interview with author, February 6, 2018).

One of the other barriers to adoption of the NoFoam System for Automotive Fire Apparatus was socialization of the technology with end users and decision-makers. The NAVFAC principal investigator and vendor who developed the technology marketed it to Navy installations by cold-calling base fire chiefs, visiting sites to provide demonstrations and training, and presenting at technical conferences (A. Drucker, interview with author, February 6, 2018). The license vendor worked with the NFPA’s governing board to update standards and codes to allow for use of a bypass system in routine testing (A. Drucker, interview with author, February 6, 2018). This level of engagement aided adoption of the NoFoam System beyond the Navy and integrated the technology into mainstream use.

B. NESDI/ESTCP PROJECT: NOFOAM SYSTEM FOR AIRCRAFT HANGAR FIRE SUPPRESSION

1. Project Background

The NoFoam System for Aircraft Hangar Fire Suppression was developed by NAVFAC under the NESDI and ESTCP programs. The system was developed to address the same environmental concerns as the NoFoam System for Automotive Fire Apparatus. Navy Policy and NFPA codes require discharge checks of the AFFF system installed in aircraft hangars to be performed every two years in order to verify that it is operable and will perform in the event of a fire (Kudo, 2011). However, discharge of AFFF must be captured, stored and disposed of as hazardous waste, which is an expensive and difficult process. Some Navy installations were not performing the required system checks due to the costs and environmental risk associated with AFFF discharge (A. Drucker, interview with author, February 6, 2018). The NoFoam System developed by NAVFAC uses a surrogate fluid, typically dyed water, to bypass the AFFF in the system while testing that the system otherwise performs as required (Kudo, 2011). The discharged test water can then be drained into the facility’s wastewater collection system, eliminating the costs and concerns with discharge and recovery of AFFF.

The NoFoam System for Aircraft Hangar Fire Suppression was developed as a retrofit module for existing piping systems complete with valves and flow meters required for testing. While each aircraft hangar AFFF system contains similar components, the layout and fire pump capacity may vary from site to site (Kudo, 2011). Because each aircraft hangar AFFF suppression system is unique, the NoFoam System must be designed for the specific installation configuration.

The NoFoam system was demonstrated successfully at two locations: the Arizona Air National Guard, Tucson in April 2008 and the Marine Corps Base Hawaii, Kaneohe

Bay in December 2008 (Kudo, 2011). The final demonstration report was published in 2011.

2. Transition Process

Like the NoFoam System for Automotive Fire Apparatus, the NoFoam System for Aircraft Hangar Fire Suppression is a proprietary system of the U.S. Navy that could be transitioned for commercial use by license agreement with a private vendor (Kudo, 2011). The EXWC/vendor team was successful at getting the NoFoam system recognized by the NFPA and the UFC as a valid method for testing AFFF systems in hangars (Kudo, 2011). However, the current barrier to adoption within the Navy is that CNIC, NAVFAC headquarters, and the fire safety community require the system to be certified through an Occupational Safety and Health Administration (OSHA) Nationally Recognized Testing Lab (NRTL) (A. Drucker, interview with author, February 6, 2018). The EXWC and vendor team are currently working with a NRTL and have testing scheduled for May 2018 (A. Drucker, email to author, April 25, 2018), but at nearly 10 years since the technology was demonstrated its adoption has been slow.

Funding the technology adoption is a common challenge in DOD and often subject to the results of an economic analysis. For the NoFoam System for Aircraft Hangar Fire Suppression, the economic analysis may vary from site to site because of the different design configurations but, in general, the retrofit module components are the same and are commercially available fire suppression system appurtenances (Kudo, 2011). However, in addition to reducing costs due to hazardous waste collection and disposal, the NoFoam system reduces impact to operations and time lost due to testing. If standard testing of the system is performed as required, the aircraft hangar would be non-operational for at least one day after testing, if a replenishment supply of AFFF concentrate is on hand (Kudo, 2011). Otherwise, the hangar would remain non-operational until the AFFF is resupplied. With the NoFoam system installed, the hangar can return to normal operations within one hour after discharge tests are completed (Kudo, 2011). The economic analysis performed for the demonstration project resulted in a 0.36 year payback and indicated significant savings to the DOD, if adopted (Kudo, 2011). There is currently no dedicated source of funding for the adoption of this technology in Navy facilities.

Following the demonstrations, both sites were given the option of keeping the NoFoam system in place for future use or having their facilities returned to its initial configuration. Because the Arizona Air National Guard facility had been performing some partial system checks, they elected to retain the NoFoam system as they would receive the financial benefits associated with the elimination of AFFF discharge during testing (Kudo, 2011). The Marine Corps elected to have the NoFoam system removed from their facility (Kudo, 2011). Since the Marine Corps Base Hawaii facility had not been performing the required tests on the AFFF system, they had not been incurring costs associated with AFFF discharge (Kudo, 2011). Perhaps a better economic analysis would have included the costs associated with loss of the facility due to a fire if the AFFF system failed because it had not been properly tested and maintained. There are a total of 364 aircraft hangars on naval installations with a plant replacement value (PRV) of $9.1 billion (Naval Facilities and Engineering Command [NAVFAC], 2018). These facilities, and the systems and equipment they house, are a significant asset to the Navy and Marine Corps. With over 500 aircraft hangar foam systems throughout the DOD, the NoFoam System for Aircraft Hangar Fire Suppression could save $25M every 2 years in AFFF recovery and disposal fees, and avoid an additional $4.6M for the purchase of AFFF solution to replace that used in the discharge checks (A. Drucker, email to author, April 25, 2018). However, the lack of installed systems to demonstrate the technology may impact future adoption unless the system is mandated for use.

C. ESTCP PROJECT: ZERO VOC, COAL TAR FREE SPLASH ZONE COATING

1. Project Background

The splash zone of a waterfront facility is the area between the lowest tidal mark and up to ten feet above the highest tidal mark (Gaughen, Pendleton, & Zarate, 2010). On Navy installations, these waterfront facilities are often constructed with steel sheet piles. Within the splash zone, the rate of corrosion of steel is more than six times that of steel under constant water immersion (Gaughen et al., 2010). This rate of corrosion is a challenge to the maintenance of Navy waterfront facilities. The two UFGS approved steel waterfront structure corrosion prevention methods are the three coat epoxy system and the coal tar epoxy system (Gaughen et al., 2010). Both systems contain high volatile organic compounds (VOC), which are considered hazardous air pollutants and regulated by the EPA. Additionally, the coal tar epoxy system contains coal tar pitch, a cancer-causing substance controlled by the OSHA (Gaughen et al., 2010). The coatings must be reapplied as often as every five years as part of ongoing maintenance. A search of waterfront facilities in the Navy and Marine Corps resulted in a total of 516 piers, wharves and bulkheads (NAVFAC, 2018). Assuming that 30 percent of these structures are constructed of steel sheet piling (Gaughen et al., 2010), the total plant replacement value (PRV) of these steel structures is $3.8 billion (NAVFAC, 2018). The total annual maintenance cost of steel piers, wharves and bulkheads at naval installations was estimated at $20 million in 2010 (Gaughen et al., 2010). These facilities directly support fleet operations.

Due to the cost and environmental risks associated with these systems, NAVFAC tested other commercially available coatings in order to find one that was more effective, more efficient and incurred reduced environmental risks than the two UFGS approved systems (Gaughen et al., 2010). None of the commercial systems were found to perform better than the existing methods. Instead, in 2002, NAVFAC utilized the Small Business Innovative Research (SBIR) program to fund two vendors for initial development of a new coating system (Gaughen et al., 2010).

The development of the Zero VOC Coal Tar Free Splash Zone Coating was broken up into three phases (Gaughen et al., 2010). Phases 1 and 2 included lab development and small-scale field testing of the coating and concluded in 2004. Phase 3 was funded under the ESTCP and included full-scale field demonstrations at two sites: Naval Air Station Pensacola, Florida and Naval Station San Diego, California, both in 2006 with final assessments performed in 2008 (Gaughen et al., 2010). One of the vendor developed coatings performed successfully in the Phase 3 demonstration.

2. Transition Process

The key to facilitating adoption of the Zero VOC Coal Tar Free Splash Zone Coating for DOD use was incorporating the performance specification into the UFGS (D. Zarate, interview with author, February 6, 2018). Additionally, the project worked to incorporate the specification into the Master Painters Institute (MPI) performance standard in order to facilitate adoption by the commercial industry, and ensure contractors were qualified and certified to apply the coating (Gaughen et al., 2010). A lack of qualified contractors was identified in the final technical report as one of the limiting factors to transitioning the technology to the field (Gaughen et al., 2010).

It is difficult to determine how widely this technology has been adopted because the programs used to develop it do not track its implementation beyond its transition into commercial standards and facilities specifications (D. Zarate, interview with author, February 6, 2018). It is expected that end-users will utilize the latest versions of the UFGS and MPI standards when developing contracts for maintenance, renovation or new construction of waterfront facilities. However, this technology has widespread application throughout the $3.8 billion worth of Navy and Marine Corps steel waterfront facilities, as well as within the private sector.

D. JCTD PROJECT: SMART POWER INFRASTRUCTURE DEMONSTRATION FOR ENERGY RELIABILITY AND SECURITY (SPIDERS)

1. Project Background

DOD's dependence on the local grid for electrical power creates a vulnerability for its mission. The majority of DOD installations purchase utilities services from commercial sources. The threat of utility outages, particularly from natural disasters and cyberattacks, are an increasing risk to continuity of operations of critical facilities and infrastructure onboard DOD installations. The SPIDERS was a Joint Capabilities Technology Demonstration (JCTD) project designed to "demonstrate a cybersecure microgrid with integration of smart grid technologies, distributed and renewable generation and energy storage on military installations for enhanced mission assurance" (NAVFAC, 2015, p. 3). SPIDERS was developed through a partnership between DOD, DOE and the Department of Homeland Security (DHS) and the demonstration was conducted in three phases, applying a “crawl, walk, run” approach over a four year period between 2011 and 2015 (B. Anderson, interview with author, February 7, 2018). Phase 1, the “crawl” phase, was completed in 2013 at Joint Base Pearl Harbor, Hawaii and included the “development of a microgrid consisting of a single distribution feeder, two electrically isolated loads, two isolated diesel generators, and an isolated photovoltaic (PV) array” (NAVFAC, 2015, p. 5). Phase 2, the “walk” phase, was completed in 2014 at Fort Carson, Colorado and consisted of a microgrid that included “three distribution feeders, seven building loads, three diesel generators, and a 1-megawatt segment of an onsite PV array, as well as five bidirectional electric vehicle chargers” (NAVFAC, 2015, p. 6). Phase 3, the “run” phase, was completed in 2015 at Camp H.M. Smith, Hawaii and consisted of a microgrid that supported the entire installation (NAVFAC, 2015). The SPIDERS performed successfully during the demonstration by maintaining power supply to the installation, withstanding simulated cyber “attacks” during testing, and improving the efficiency and reliability of generators while integrating renewable energy sources (NAVFAC, 2015).

2. Transition Process

NAVFAC served as the transition manager for the SPIDERS technology with the ultimate goal of transitioning the microgrid design to the federal, state, local government, and private sector levels (B. Anderson, interview with author, February 7, 2018). Within the Navy, the transition manager was focused on adopting the design to support Navy installations at remote islands such as Diego Garcia, San Clemente Island and San Nicholas Island. To facilitate transition, NAVFAC published the demonstration’s phase and final reports to DOE’s Federal Energy Management Program (FEMP) website, held “industry days” to present findings to stakeholders at all levels, developed a new UFC for cybersecurity of shore facilities and design guide for microgrids (B. Anderson, interview with author, February 7, 2018). However, despite the efforts to transition the technology and the support of the joint partners, the SPIDERS microgrid has not been adopted.

A cost-benefit analysis of SPIDERS Phase I concluded that, with a $5.2 million price tag, the initial phase of the project had a negative return on investment and represented a "poor business decision" when evaluated on strictly economic terms (Leewright, 2012, p. 33). The SPIDERS JCTD investment totaled over $50 million although an economic analysis of the second and third phases was not readily available. Ideally, SPIDERS would have been recommended to the Secretary of the Navy by NAVFAC or the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN (RD&A)) for Acquisition Category (ACAT) designation. ACAT designation would have resulted the technology becoming a program of record with dedicated congressional funding that would have supported widespread adoption of the SPIDERS technology within DOD installations. However, no additional funding was authorized for the SPIDERS JCTD beyond the final demonstration phase.

The transition manager argued that attempts to transition SPIDERS were met by a lack of understanding within NAVFAC of the need for cybersecurity of installation utility infrastructure (B. Anderson, interview with author, February 7, 2018). Adametz et al. argued in their 2016 review of the Navy's strategy for cybersecurity of industrial control systems that "internally, NAVFAC culture is a concern" because many view cybersecurity "as a CIO [Chief Information Officer] problem" and not one that affects lower echelon NAVFAC missions (Adametz, Groesbeck, & Quibilan, 2016, p. 43). In a 2017 NPS thesis on NAVFAC investments in energy technologies, the authors interviewed NAVFAC employees and received a range of responses on the importance of cybersecurity with some arguing that a "cyberattack did not pose an immediate threat to their mission" (Adams & Hartner, 2017, p. 31). This lack of support resulted in the failure to adopt the SPIDERS technology on naval installations.

Although the SPIDERS architecture was not adopted, the lessons learned have fueled investments in other microgrid research and design guides since the demonstration project was completed in 2015. Figure 4 shows a timeline of related projects. Additionally, in 2016 NAVFAC was designated as the technical authority for cybersecurity of industrial control systems ashore (Adametz et al., 2016). This new authority has brought an increased focus to the importance of developing a more robust strategy to secure naval utility infrastructure and industrial control systems against cyberattacks. However, it remains that "there is no identified program of record so any funding identified for this effort will be at the expense of another requirement barring Navy top line relief" (Adametz et al., 2016, p. 39).

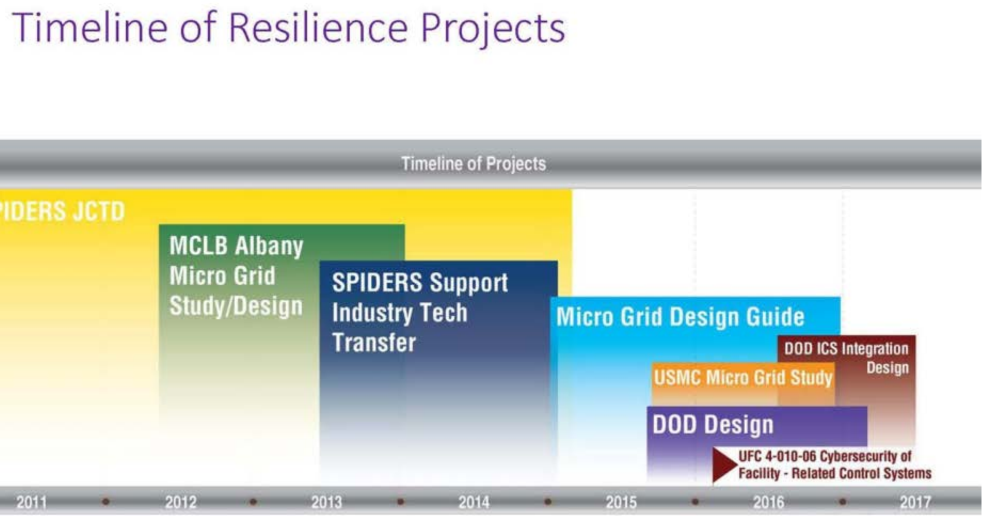


Figure 4. Micro-grid Research and Design Guides Related to SPIDERS Technology. Source: Miyagawa (2017).

E. TECHVAL PROJECT: MAGNETIC BEARING CHILLER COMPRESSOR

1. Project Background

There have been a number of initiatives at Navy installations designed to reduce energy consumption in existing facilities. Installation energy managers often plan building renovation projects to upgrade lighting and heating, ventilation, and air conditioning (HVAC) systems using energy efficient technologies. These projects must be programmed and compete for funding through various sources. Some of these sources of funding include sustainment, restoration and modernization (SRM) funding, Energy Savings Performance Contracts (ESPC) and Utility Energy Service Contracts (UESC). In order to be eligible for funding, these projects must have a savings-to-investment ratio (SIR) greater than 1.0 and are evaluated based on their proposed energy return-on-investment (eROI) and simple payback period. These projects typically employ commercially available and proven technologies that provide known efficiency and performance characteristics, allowing for the energy savings necessary to successfully compete for funding.

The TECHVAL program was designed to demonstrate and validate newer commercial energy technologies, on Navy installations, that may or may not have been proven in the private sector. In 2002, the TECHVAL program manager at EXWC learned about a newer technology known as the magnetic bearing chiller compressor for use in building HVAC systems. Traditional chiller compressors utilize oil to lubricate bearings in order to reduce friction in the centrifugal system. The magnetic bearing compressor, by its nature requires no lubrication and friction is reduced because there is no contact between the bearings and the compressor shaft. This design, theoretically, increases efficiency by up to 30 percent over traditional compressors (P. Kistler, email to author, January 31, 2018). The Navy TECHVAL program demonstrated the commercially available magnetic bearing chillers at three locations in order to validate their suitability on Navy installations in different climate conditions: Newport, Rhode Island and San Diego, California from 2004–2006, and Jacksonville, Florida from 2006–2008 (P. Kistler, email to author, January 31, 2018). The demonstrations performed successfully with the following observed energy savings: Newport - 65 percent, San Diego – 40 percent and Jacksonville – 41 percent (P. Kistler, email to author, January 31, 2018). Based on the installed costs and observed energy savings, the project’s calculated simple payback period for Newport, San Diego and Jacksonville was 3.8, 8.4 and 7.0 years, respectively (P. Kistler, email to author, January 31, 2018). Since the TECHVAL demonstration, magnetic bearing chiller compressors have been widely adopted by the Navy (P. Kistler, email to author, January 31, 2018).

2. Transition Process

The TECHVAL demonstration of the magnetic bearing chiller compressor facilitated adoption by validating the performance characteristics advertised by the manufacturers. Once the technology had been proven on Navy installations, the

TECHVAL PM requested updates to the UFGS language that would allow for magnetic bearing chiller compressors to be installed in facilities (P. Kistler, email to author, January 31, 2018). The language in the NAVFAC Design-Build Request for Proposals standard template for contracting was also updated to include the specification for magnetic bearing chiller compressors (P. Kistler, email to author, January 31, 2018). These changes were necessary for end users to issue and award contracts for magnetic bearing chiller installations without requesting waivers from NAVFAC headquarters.

In addition to updating the guide specifications, the TECHVAL PM presented the demonstration project findings at the annual Department of Energy (DOE) conference and trade show, currently known as Energy Exchange, and other industry technical conferences (P. Kistler, interview with author, February 7, 2018). He also presented the findings to installation energy managers and end users at the Navy's Civil Engineer Corps Officer School (CECOS) energy manager training courses held approximately four times a year (P. Kistler, email to author, January 31, 2018). Through these engagements, the PM educated stakeholders on proven technologies and advertised the ability of the TECHVAL program to validate new technologies.

One issue that resulted in several initial installations of the technology was that maintenance personnel unfamiliar with the magnetic bearing chillers were adding oil to the compressors in accordance with their standard procedures for rotary-screw chillers. This practice caused a number of chiller failures and threatened adoption. However, upon learning of this issue, the TECVAL PM facilitated training of maintenance personnel and disseminated lessons learned through previously mentioned measures in order to prevent future occurrences.

As with other technology transfer programs, the TECHVAL program did not track the adoption of the magnetic bearing chiller compressor so it is unknown how many are currently installed (P. Kistler, interview with author, February 7, 2018). However, the incorporation of the technology into specifications and contract document templates along with the engagement of contractor and end-user stakeholders transitioned the magnetic bearing chiller compressor into mainstream use for the Navy. The benefit of the TECHVAL demonstration of the magnetic bearing chiller compressor was that it proved the benefit of the technology in Navy installations and enabled energy and facility managers to confidently invest in the technology at their sites. Today, the magnetic bearing chiller compressor is often the first choice of energy managers when programming projects for efficient replacements of existing chillers that have reached the end of their service life.

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IV. ANALYSIS

The first step in the analysis was to take a broad overview of the cases to look for any common themes. Table 6 details the associated TTP, number of demonstration sites, whether the TTP included a technology integration plan, the type of funding associated, whether any associated UFGS, UFC or industry specifications were updated, how the technology was developed (internally or commercially), and whether the technology was ultimately adopted.

The sample size is too small to perform a substantial analysis based solely on the factors included in the overview. However, it is interesting to look at some of the relationships present in this sample of projects. Three of the five technologies explored were adopted within the Navy. The transition manager was successfully able to have the associated specifications and standards updated to include the use of the technology in each of the three projects that were adopted: the NoFoam System for Automotive Fire Apparatus, Splash Zone Coating and Magnetic Bearing Chiller Compressor. This appears significant and is further explored in the application of the models below.

Table 6. Summary of Cases Analyzed and their Outcomes

Case	TTP	# Demonstration Sites	Tech Integration Plan	Funding	Criteria/ Specs Updated	Industry Standards Updated	In-house or COTS Developed	Adopted
NoFoam for Automotive Fire Apparatus	NESDI/ESTCP	3	X	RDT&E, O&M	X	X	In-house	X
NoFoam for Hangar AFFF Systems	NESDI/ESTCP	2	X	RDT&E			In-house	
Splash Zone Coating	SBIR/ESTCP	2	X	RDT&E	X	X	In-house	X
SPIDERS	JCTD	3	X	RDT&E			In-house	
Magnetic Bearing Chiller Compressor	TECHVAL	3	X	Geothermal	X	N/A	COTS	X

The timelines for adoption varied for the different cases. The NoFoam System for Automotive Fire Apparatus took five years to complete from initial development to adoption (Kudo, 2011). The Splash Zone Coating development was initiated in 2005 and the final report was published in 2010. The Magnetic Bearing Chiller Compressor TECHVAL program was initiated in 2003, demonstrated from 2004-2008, and by 2011 the technology had been adopted at 17 Navy and Marine Corps installations (P. Kistler, email to author, January 31, 2018).

A. ARL FRAMEWORK ANALYSIS

The ARL framework was used to determine a readiness level for each of the dimensions: systems-level technology integration, stakeholders and processes. The levels were then aggregated to establish an ARL for each project. A summary of the ARL levels by dimension and case are shown in Table 7. The aggregate ARL for each project accurately represented the project outcome.

Table 7. Analysis of Cases using ARL Framework

Case	Aggregate ARL	ARL Dimension		
		Systems-Level Technology Integration	Stakeholders	Processes
NoFoam for Automotive Fire Apparatus	6 - Adopted	6	6	6
NoFoam for Hangar AFFF Systems	4 - Representative Demonstration	5	4	4
Splash Zone Coating	5 - Fully Adoptable	5	5	5
SPIDERS	4 - Representative Demonstration	4	4	4
Magnetic Bearing Chiller Compressor	6 - Adopted	6	6	6

1. NoFoam System for Automotive Fire Apparatus

The NoFoam System for Automotive Fire Apparatus project received an ARL 6 overall because each of the three dimensions had a readiness level of 6. For the systems-level technology integration dimension, a readiness level of 6 was assigned because the technology is being used at many installations. During the project's demonstration phase, the technology was validated and accepted by the various stakeholders to include the installation fire departments, fire inspection personnel, the UFC/UFGS criteria managers and the National Fire Protection Association. Extensive training was conducted by the vendor during system installations both during and beyond the demonstration project. The technology is considered fully adopted.

2. NoFoam System for Aircraft Hangar Fire Suppression

The NoFoam System for Aircraft Hangar Fire Suppression (Hangar AFFF Systems) project received an ARL 4 overall. The technology was demonstrated at two sites with successful performance receiving a systems-level technology integration readiness level 5. However, in the stakeholder and processes dimensions, the technology only received a readiness level 4. The technology was not validated and accepted by all stakeholders (including the Marines who opted to have the demonstration project removed from their facility) because the facility owners and fire protection community would not accept the technology until it had been independently tested by an OSHA NRTL. Without the independent certification, all technical authorities have not accepted the technology and the process dimension is limited to an ARL 4. The technology has not yet been adopted.

3. Zero VOC, Coal Tar Free Splash Zone Coating

The Splash Zone Coating project received an ARL 5 overall. The system is considered fully adoptable as its performance was proven during the demonstration project and the UFC/UFGS and industry standards were updated to include the technology. However, the TTP did not track how widely the coating has been used. It is possible that the technology could be considered fully adopted and an ARL 6 for each category would be more appropriate.

4. SPIDERS

The SPIDERS cybersecure micro-grid received an ARL 4 overall and in each of the framework dimensions. The technology was unable to move beyond the demonstration project because it was not fully accepted by all stakeholders, was not budgeted for procurement and was not implemented operationally beyond the demonstration sites.

5. Magnetic Bearing Chiller Compressor

The magnetic bearing chiller compressor technology received an ARL 6 and in each framework dimension because the technology is in use at multiple installations. During the demonstration project, the technology's performance was validated and accepted by stakeholders at the user level. The transition manager worked with the criteria managers to update the UFC/UFGS and, since it was a commercially available product, its use was already established in private industry. The technology is considered fully adopted.

B. ROGERS' FIVE FACTORS CASE ANALYSIS

Rogers' (2003) research focused on the perception of product performance in five factors as necessary for technology adoption. Those factors are: relative advantage, compatibility, complexity, trialability and observability. Each case was analyzed based on those five factors and a summary is provided in Table 8. An "X" in the table indicates that the factor was demonstrated in the corresponding case study.

Table 8. Summary of Case Analysis using Rogers' Five Factors

Case	Rogers' Factors				
	Relative Advantage	(HIGH) Compatibility	(LOW) Complexity	Trialability	Observability
NoFoam for Automotive Fire Apparatus	X	X	X	X	X
NoFoam for Hangar AFFF Systems	X	X	X	X	
Splash Zone Coating	X	X	X	X	X
SPIDERS				X	X
Magnetic Bearing Chiller Compressor	X	X	X	X	X

1. NoFoam System for Automotive Fire Apparatus

The NoFoam System for Automotive Fire Apparatus provided a functional and economic advantage over the existing system because it removed the requirement to collect and dispose of AFFF as a hazardous waste following periodic tests of the system. The system was highly compatible with existing equipment because it came as a retrofit kit that could be installed with commercially available components. The ease of operation also addressed the factor of complexity because it did not require significant re-training of firefighting personnel. The technology was demonstrated for numerous personnel at multiple locations addressing Rogers' factors of trialability and observability. This technology was fully adopted.

2. NoFoam System for Aircraft Hangar Fire Suppression

Similar to the NoFoam System for Automotive Fire Apparatus, the technology designed for hangar AFFF systems provided an advantage over the existing system by removing the requirement to collect and dispose of hazardous waste. The retrofit kit was also highly compatible with existing systems and operations. However, it was slightly more complex because the system had to be designed specifically for each hangar. The unique design requirement contributed to higher costs but did not detract from function. The technology was trialable and demonstrated in two different locations. However, the Marines requested that the technology be removed from their hangar following the demonstration project, resulting in less observability as fewer sites were available for potential adopters to see the technology perform. The NoFoam System for Aircraft Hangar Fire Suppression was not fully adopted.

3. Zero VOC, Coal Tar Free Splash Zone Coating

The Zero VOC, Coal Tar Free Splash Zone Coating met all of Rogers' factors for adoption. The technology provided a relative advantage to other coatings because it was safer for the environment and longer-lasting than existing systems. It had high compatibility with existing infrastructure and its application was not complex and could be performed with periodic maintenance of waterfront facilities. It could also be applied to new construction or for spot repairs of damaged sheet piles. The technology was demonstrated at two Navy installations in different geographic locations which contributed to meeting the trialability and observability factors. The splash zone coating technology was adopted.

4. SPIDERS

The SPIDERS technology did not meet Rogers' five factors for adoption. The technology was highly complex, very expensive, required extensive design and planning to be compatible with infrastructure at various locations. The technology was developed and demonstrated in three phases, each at a different site, which did contribute to its trialability. However, much of the configuration was classified and, therefore, limited its observability. The technology was not adopted.

5. Magnetic Bearing Chiller Compressor

The magnetic bearing chiller compressor was a commercially available product demonstrated at Navy installations under the TECHVAL TTP. It offered a relative advantage to existing systems by increasing energy efficiency and thereby lowering energy and life-cycle costs. The technology was not significantly more complex, and actually required less maintenance, than existing chiller technologies. It demonstrated high compatibility since it could be installed as a compressor replacement on existing systems or as a whole new chiller system. The demonstration project was performed at three locations, meeting the trialability factor, and its performance was observable as it was widely available in the private industry. This technology was fully adopted within the Navy.

C. ENERGY CULTURES FRAMEWORK CASE ANALYSIS

Using the Energy Cultures framework for analysis, the cases are discussed with respect to each of the three core components—material culture, cognitive norms, and energy practices. The component of material culture is largely addressed in these cases through the demonstrated performance of the new technology. However, the cognitive norms and energy practices (or environmental, in some cases) may have been less affected, and this may help to explain why a technology was not adopted.

1. NoFoam System for Automotive Fire Apparatus

The NoFoam System for Automotive Fire Apparatus case provides a great example of the interrelationship between the three core components of the Energy Cultures framework. The opportunity for change was present because the cognitive norms and energy (environmental) practices of the affected culture—the fire protection community, in this case—were not aligned. The firefighters integrated training with the requirement to perform periodic operational checks of the AFFF system, indicating that the community values training, safety and quality control. However, due to concerns about cost and environmental damage, the community was forced to consider tradeoffs between their values and their practices. Training and quality control checks of the existing AFFF system was expensive and unsafe but failing to train and test the system could be dangerous and costly if the system failed to perform in the event of a fire. The NoFoam System demonstrations addressed the material culture component of framework by providing a cost-effective solution using commercially available materials to address the environmental concern associated with periodic discharge checks of the existing AFFF system. The value of the system at addressing the concerns was sufficient for the criteria managers to incorporate changes to the applicable specifications and codes. However, the demonstrations alone were not enough to facilitate adoption. While these technology demonstrations brought the norms, culture and practices into better alignment—especially for those fire protection community members at higher echelons—the cost of the system prevented a complete alignment of norms and practices for operators at the field level. The challenge they now faced was whether to recommend purchase of new or additional firefighting vehicles or the purchase of retrofit kits for existing vehicles. The material solution came in the form of funding from the PPEP which facilitated purchase of the NoFoam System for numerous bases.

2. NoFoam System for Aircraft Hangar Fire Suppression

Similar to the NoFoam System for Automotive Fire Apparatus, the NoFoam System for Aircraft Hangar Fire Suppression provides a material solution to address a misalignment of cognitive norms and environmental practices. However, the technology has yet to be adopted. This project is more challenging to analyze because the demonstrations were conducted at a Marine Corps installation and at an Air National Guard installation. The Marine Corps requested that the system be removed from their facility following the demonstration project. It is unlikely that this community values safety, training and quality control any less than the Navy firefighting community but, according to the technical report, their practices had been adjusted (they performed the required periodic system checks except for those requiring AFFF discharge) in order to better align with their cognitive norms concerning cost. The Air National Guard was more accepting of the technology because they recognized a direct economic benefit in addition to the safety and environmental benefits. However, the higher echelon firefighting community within the Navy has not yet accepted the material solution and requires additional independent testing before incorporating the technology into specifications and codes. It is possible that there are various degrees of risk tolerance within the cultures of the different branches of service that the NoFoam System does or fails to address and this has slowed its adoption.

3. Zero VOC, Coal Tar Free Splash Zone Coating

In the case of the Zero VOC, Coal Tar Free Splash Zone Coating, an opportunity for change arose because the three components were not aligned. The existing commercially available coatings were environmentally harmful and did not align with the changing values and practices of the coatings industry and facility owners caused by EPA and OSHA guidance regarding the health and environmental risks associated with use of VOC and coal containing products. The successful development and demonstration of a new product that aligned with the cognitive norms and practices of the industry allowed for the solution to be adopted.

4. SPIDERS

The SPIDERS project presents a challenge to this analysis using the Energy Cultures framework. As a joint program, the various organizations and echelons within them each have distinct norms, cultures and practices. There is insufficient evidence collected to analyze each of framework’s components. The case study only discusses the adoption of the technology from the NAVFAC role as the transition manager. Applying the framework through that lens, the technology failed to be adopted because there was not sufficient misalignment between the cognitive norms, practices and the material culture. In other words, the opportunity for change was not present because the components were aligned in the status quo. Cybersecurity is the characteristic that distinguishes SPIDERS from other microgrids. The case study implies that the culture within NAVFAC does not value cybersecurity over cost and functionality, and, therefore, other material solutions may be considered as more viable alternatives. However, the case also discussed changes within NAVFAC culture and policies in recent years that may indicate a change in values that would make the SPIDERS technology more acceptable. For now, however, the technology has not been adopted.

5. Magnetic Bearing Chiller Compressor

The magnetic bearing chiller compressor case study provides another example of opportunity arising for a material solution to meet the shifts in energy practices and cognitive norms. As Navy facilities seek to balance cost reduction with energy savings, the solution often comes in the form of affordable, energy efficient technologies. The magnetic bearing chiller compressor provided just this sort of material solution. The project successfully demonstrated that the magnetic bearing chiller compressor was more energy efficient and had a lower life-cycle cost than traditional rotary screw chillers, both of which translated to direct economic benefits. The commercial availability of the product made adoption easier because it could be purchased using O&M funding to replace existing systems during restoration and modernization activities.

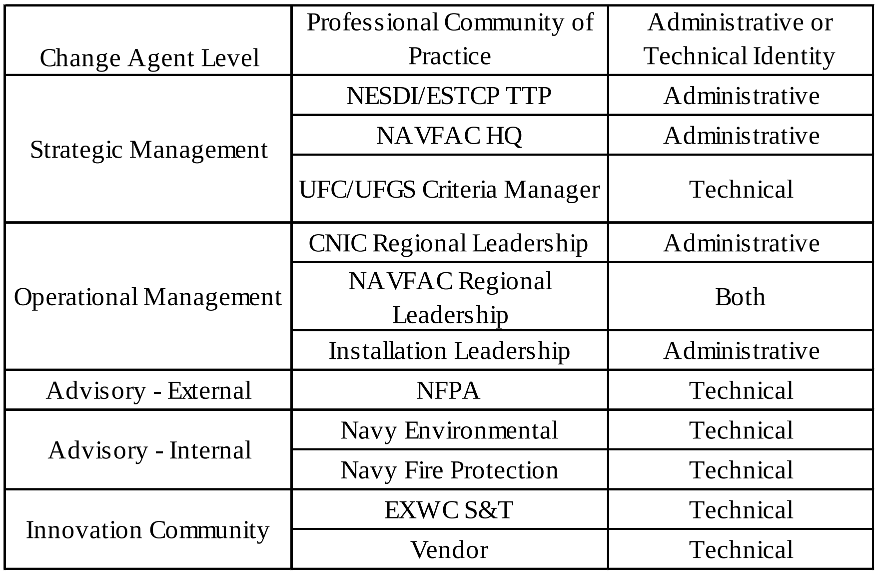
D. PROFESSIONAL COMMUNITIES OF PRACTICE CASE ANALYSIS

Plieth et al. (2013) researched the concept of change agent roles in the innovation process within a single innovation community. This study expands the work of Plieth et al. to the various communities of practice involved with the demonstration projects examined in each case included herein. Within these communities, there may be an overlap of professional backgrounds and expertise. For example, professional engineers exist within the S&T, administrative and fire protection communities. Their specialty (e.g., fire protection versus civil/environmental) and whether they identify more with their organization or their profession can significantly impact their support for a given technology. Change agents within those communities are critical to granting required clearances in technology adoption processes. This analysis breaks down each community involved in the case study, assigns them to one of the change agent levels as presented in the literature, and evaluates whether the community presents an administrative (organizational) or technical (professional) identity.

1. NoFoam System for Automotive Fire Apparatus

In the case of the NoFoam System for Automotive Fire Apparatus, the stakeholder communities are presented in Table 9. Three communities are present at the strategic management level: NESDI/ESTCP as the funding owner for the demonstration project, NAVFAC as the executing agent, and the UFC/UFGS criteria manager as the strategic level technical authority. While NAVFAC executive leadership is made up of professional engineers and architects, at the headquarters level the individuals function in more of an administrative role and, therefore, are more likely to identify with the organization than with their professions. The operational management level consists of the CNIC and NAVFAC regional leadership and the local installation leadership, all acting with administrative identities. However, at the NAVFAC regional level, the identity could be both administrative and technical, depending on the individual who fills the change agent role. At the advisory level, external advisors include the NFPA with a technical role. The internal advisory level includes individuals within the Navy environmental and fire protection communities, likely serving with technical identities. Finally, the innovation community includes the EXWC S&T team and the vendor, both with technical identities.

Table 9. Communities of Practice within the NoFoam System for Automotive Fire Apparatus Case Study



Change Agent Level	Professional Community of Practice	Administrative or Technical Identity
Strategic Management	NESDI/ESTCP TTP	Administrative
	NAVFAC HQ	Administrative
	UFC/UFGS Criteria Manager	Technical
Operational Management	CNIC Regional Leadership	Administrative
	NAVFAC Regional Leadership	Both
	Installation Leadership	Administrative
Advisory - External	NFPA	Technical
Advisory - Internal	Navy Environmental	Technical
	Navy Fire Protection	Technical
Innovation Community	EXWC S&T	Technical
	Vendor	Technical

Table 9 helps to visualize the various communities, the hierarchy of their change agent role, their identities and to understand the number of clearances required for transition to adoption. In the NoFoam System for Automotive Fire Apparatus case, key change agents at the implementation phase of the project included the UFC/UGFS criteria manager, NFPA, Navy fire protection community, the vendor and the EXWC principal investigator.

2. NoFoam System for Aircraft Hangar Fire Suppression

In the case of the NoFoam System for Aircraft Hangar Fire Suppression, the stakeholder communities are presented in Table 10. The communities at the strategic management level include the NESDI/ESTCP TTP as the funding owner for the demonstration project, NAVFAC as the executing agent, and the UFC/UFGS criteria manager as the strategic level technical authority. The operational management level consists of the local installation leadership, likely identifying with an administrative identity. External advisors in this case include the NFPA and the OSHA NRTL. The internal advisory level includes the facility owners (since the demonstration was not conducted in Navy facilities) with administrative identities and the fire protection community with a technical identity. The innovation community consists of the EXWC S&T team and the technology vendor.

Table 10. Communities of Practice within the NoFoam System for Aircraft Hangar Fire Suppression Case Study

Change Agent Level	Professional Community of Practice	Administrative or Technical Identity
Strategic Management	NESDI/ESTCP TTP	Administrative
	NAVFAC HQ	Administrative
	UFC/UFGS Criteria Manager	Technical
Operational Management	Installation Leadership	Administrative
Advisory - External	NFPA	Technical
	OSHA NRTL	Technical
Advisory - Internal	Facility Owner	Administrative
	Fire Protection	Technical
Innovation Community	EXWC S&T	Technical
	Vendor	Technical

The NoFoam System for Automotive Fire Apparatus case differed from the NoFoam System for Automotive Fire Apparatus because it was demonstrated in non-Navy facilities. A “facility owner” community was added to represent the non-Navy entity. The facility owner community and the requirement to have the technology validated by an OSHA approved NRTL, introduced two additional clearances to the innovation process. The key change agents at the implementation phase of the project included NAVFAC HQ, the UFC/UGFS criteria manager, the NFPA, the facility owner, the fire protection community, the vendor and the EXWC principal investigator. Approval from NAVFAC HQ and the fire protection community is still pending.

3. Zero VOC, Coal Tar Free Splash Zone Coating

The organization of communities and change agents in the case of the Splash Zone Coating is shown in Table 11. Similar to the previous two cases, the strategic management level was comprised of the ESTCP TTP, NAVFAC HQ and the UFC/UFGS criteria manager. The operational level consisted of the installation leadership. The external advisory level included the contractors and the MPI as representatives from the coatings industry and the internal advisory level included the facility owner. The innovation community included the EXWC team.

Table 11. Communities of Practice within the Zero VOC, Coal Tar Free Splash Zone Coating Case Study

Change Agent Level	Professional Community of Practice	Administrative or Technical Identity
Strategic Management	SBIR/ESTCP TTP	Administrative
	NAVFAC HQ	Administrative
	UFC/UFGS Criteria Manager	Technical
Operational Management	Installation Leadership	Administrative
Advisory - External	Vendor	Technical
	MPI	Technical
Advisory - Internal	Facility Owner	Technical
Innovation Community	EXWC S&T	Technical

The critical change agents in this case study were the TTP (as funding agent), the MPI and the UFC/UFGS criteria managers. Adoption of this technology was facilitated mostly by incorporating it into DOD and industry specifications.

4. SPIDERS

The various communities of practice within the SPIDERS JCTD are shown in Table 12. The strategic management level included the DOD, DOE, DHS and service leadership. The operational management level included NAVFAC HQ as the transition manager and the UFC/UFGS criteria managers. Contractors served as external technical advisors. Internal technical advisors included the U.S. Army Corps of Engineers Construction Engineering Research Lab (USACE-CERL) and EXWC (NAVFAC, 2015). The innovation community was composed of contractors, the U.S. Army Tank and Automotive Research and Engineering Center (TARDEC), and five national laboratories (NAVFAC, 2015).

Table 12. Communities of Practice within the SPIDERS Case Study

Change Agent Level	Professional Community of Practice	Administrative or Technical Identity
Strategic Management	DOD	Administrative
	DOE	Administrative
	DHS	Administrative
	Service Leadership	Administrative
Operational Management	NAVFAC HQ	Administrative
	UFC/UFGS Criteria Manager	Technical
Advisory - External	Contractors	Technical
Advisory - Internal	USACE - CERL	Technical
	EXWC	Technical
Innovation Community	Contractors	Technical
	US Army TARDEC	Technical
	Five National Labs	Technical

Since the case study focused on the technology adoption from the perspective of NAVFAC acting as the transition manager, there may be other communities and change agents not presented here. This project differs from the others in the level and number of communities at the strategic management level. It is also unique in that there is a distinct divide between administrative and technical identities at the operational management level. It is difficult to know where all of the critical change agents exist. It is quite possible that the lack of technical identity within the higher echelons, particularly with respect to the complex world of cybersecurity, created a barrier to understanding the utility and advantage of the SPIDERS system over other possible solutions. The level of acceptance within the other communities is not known from the case study. What is known is that the technology was not accepted above the NAVFAC HQ level, and, therefore, failed to be fully adopted.

5. Magnetic Bearing Chiller Compressor

The communities of practice in the case of the magnetic bearing chiller compressor are presented in Table 13. This case differs from the others because it largely required acceptance at the lower change agent levels. The demonstration project proved the technology's performance claims and its commercial availability likely contributed to its acceptance by the criteria manager at the strategic level. However, the transition manager targeted facility owners and energy managers through education in order to push adoption at a wider level. These two communities proved to be the critical change agents.

Table 13. Communities of Practice within the Magnetic Bearing Chiller Compressor Case Study

Change Agent Level	Professional Community of Practice	Administrative or Technical Identity
Strategic Management	CNIC	Administrative
	NAVFAC HQ	Administrative
	UFC/UFGS Criteria Manager	Technical
Operational Management	CNIC Regional Leadership	Administrative
	NAVFAC Regional Leadership	Both
	Installation Leadership	Administrative
Advisory - External	Commercial Industry	Technical
Advisory - Internal	Energy Manager	Technical
	Facility Owner	Technical
Innovation Community	EXWC S&T	Technical

E. GARBAGE CAN MODEL CASE ANALYSIS

1. NoFoam System for Automotive Fire Apparatus

The NoFoam System for Automotive Fire Apparatus is a good example of the alignment of the problem, policy and politics stream in the garbage can model. In this case, the problem is that firefighting personnel cannot cost-effectively perform required operational checks on the AFFF discharge systems on firefighting vehicles because the discharged foam is considered hazardous waste and requires special handling and disposal. The policy is to install a retrofit kit made of inexpensive, commercially available components to bypass the foam system and use water for operational checks. The politics is the decision of the firefighting and fire safety communities to accept this particular policy alternative as an acceptable solution to the problem. The technology transition manager and the product vendor act as policy entrepreneurs working to lobby the technology system to the stakeholders for approval.

2. NoFoam System for Aircraft Hangar Fire Suppression

In the case of the NoFoam System for Aircraft Hangar Fire Suppression, the policy window has yet to open for the three streams to couple. The problem is identical to the problem with the AFFF system for firefighting vehicles—the hangar AFFF system cannot be tested without the facility incurring costs to collect and dispose of the hazardous foam. The policy solution is similar, although slightly more complex since each installation requires a unique system design. However, while the problem and policy streams have been coupled within the garbage can, the politics stream has not. It is not clear what policy alternatives, if any, are in the garbage can or if the facility owner and criteria manager stakeholders perceive the issue as a problem. In other words, we do not fully know why the politics stream has not coupled with the problem and policy streams. The model only explains that all three streams have not been coupled and so the technology has not been adopted. The policy entrepreneurs are the vendor and the technology transition manager.

3. Zero VOC, Coal Tar Free Splash Zone Coating

In the case of the Zero VOC, Coal Tar Free Splash Zone Coating, the problem, policy and politics streams coupled within the garbage can with the technology transition manager acting as the policy entrepreneur. The problem was that the existing commercially available coatings for use in the splash zone were harmful to the environment and expensive to maintain. No commercially available alternatives existed. The policy solution was the development, through the demonstration project presented in the case, of a new material that was environmentally safe and cost-effective. The politics stream coupled with the problem and policy streams resulting in a change to the industry standards and UFC/UFGS. It is through this coupling of streams that adoption of the technology occurred.

4. SPIDERS

The SPIDERS project resulted in a clear policy solution to address concerns related to the cybersecurity of microgrids that integrated smart controls, renewable energy and energy storage to support mission critical facilities and operations on military installations. However, it appears from the case study that the issue may not have risen to the level of a problem, at least in the eyes of the politics stream. Without a problem stream, the politics and policy streams cannot converge into action. It also is not clear what other policy alternatives may have existed in the garbage can at the time the SPIDERS project was completed. It is possible that even if the problem stream existed, there was no appetite within the politics stream to couple with this specific policy solution. This could explain why the SPIDERS technology was not adopted.

5. Magnetic Bearing Chiller Compressor

The magnetic bearing chiller compressor case study is an example of a policy stream entering the garbage can before the problem and politics streams. The technology (a potential policy solution) was already commercially available. The TECHVAL demonstration project helped to elevate the energy inefficient rotary screw chillers on Navy installations from an issue to a problem. The transition manager, acting as the policy entrepreneur, aided the coupling of the problem, policy and politics streams by diligently communicating the technology’s successful performance in the demonstration project to stakeholders at all levels. This coupling of problem, policy solution and politics could explain the adoption of the magnetic bearing chiller compressor technology in Navy installations.

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V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Existing technology transition programs are product-focused and address Rogers' five factors—relative advantage, compatibility, complexity, observability, trialability—through the innovation process. But this is only part of the challenge. A product focus can help shape perceptions that influence decision making but it does not go far enough to address the cultural and resource barriers that challenge adoption. It is difficult to apply a one-size-fits-all process to technology transfer as the various TTPs have different goals, funding sources, stakeholders and technical approving authorities.

Transition is defined as the point where the technology leaves the TTP—whether that is to another federal program, to industry for further development or to an acquisition program for the benefit of an end user—and adoption is generally defined as the point at which technical specifications are incorporated into the UFGS, UFC or industry standards. None of the TTPs formally measured or reported how widely used the technology became once it was transitioned or adopted. It was generally assumed that once the specifications or standards were updated, that users at the field level adapted their local processes to incorporate the latest versions and this ensured that the technology was widely diffused. This is an area that could use improvement as clearly defining the term "adoption" is necessary in order to track and report outcomes.

S&T professionals recognize that challenges exist beyond the technology. On the surface, the barriers to technology adoption appeared to be a lack of funding, a lack of stakeholder support, or both. Looking deeper, in the three successful cases, the transition managers were able to, consciously or not, recognize the various communities of practice and the change agents within them. They recognized that the culture within the organization or community was a potential barrier. They engaged change agents at all four levels in order to garner support, secure resources, and receive necessary technical approvals.

The technology, at a minimum, must meet Rogers' five factors in order to be accepted. In addition, it must address the values and norms within the various communities of practice affected. The goal of the transition manager should be to minimize the number of decision points and clearances in the innovation process. This is achievable if the transition manager understands the culture, develops strategic communications, and targets that communication to the change agents—especially the funding sources and criteria managers.

The answer to the final research question, "How might ARLs aid or improve technology adoption at Navy installations?" is this: ARLs, like the other frameworks discussed, identify potential barriers and help focus and prioritize a program's limited resources on technology projects with the greatest degree of successful adoption. The DOD seems to prefer linear, rational, stage-gate processes in technology development. However, technology transfer is a fluid, non-linear process (Ferlie et al., 2005). Therefore, a framework designed to facilitate adoption must be non-linear but comprehensive and structured enough to be applicable to various TTPs with different goals and approving authorities. The ARL framework could be improved by expanding on the stakeholder concept to more specifically address culture within professional communities of practice, and the roles of change agents at different hierarchical levels throughout the process. It is also important that a strategic communication and marketing plan be considered and included in the framework long before ARL 6 to help "soften up" (Kingdon, 2003) decision-makers.

B. RECOMMENDATIONS

The transition managers interviewed in the case studies were very experienced and held long careers in NAVFAC. They have built relationships with stakeholders in various other communities to include industry, criteria managers and users at the installation level. The knowledge and wisdom they possess is invaluable.

From these interviews, and the literature review, the following recommendations are provided for consideration in future technology transition-to-adoption initiatives:

- Implement a process to track technology adoption beyond the demonstration project. This may require changes to policy that will allow transition managers to be funded to perform this additional work but it is important to understanding the effectiveness of a TTP and any framework that may be used to improve outcomes.

- Develop a strategic communications plan; identify change agents at various organizational levels and target them to become champions of the proposed technology. This requires a great deal of networking and support from leadership to encourage sharing of information at technical conferences and symposia as well as in training environments.

- This research is largely focused on NAVFAC as the projects highlighted were executed by EXWC under the various TTPs. In this context, it is very important that transition managers be educated on DOD acquisition processes and NAVFAC business process, in order to understand the decision-making challenges faced by users, particularly public works personnel, on Navy installations.

C. FUTURE RESEARCH

Van de Ven (2017) said, "It is primarily through repeated trials and the accumulation of learning experiences across these trials that an organization can build its repertoire of competencies to progressively increase its odds of innovation success" (p. 41). Study of the technology transition process across various programs helps to refine the process in a way that better supports technology adoption. Some of the limits of this research study and recommendations for further research are as follows:

- This study was limited to five cases across several TTPs but within the same organization—NAVFAC EXWC. Analyzing multiple case studies within a single TTP and/or across multiple organizations may provide for more inference and establish criteria that enables a quantitative analysis.

- Requiring TTPs to track adoption outcomes after completion of demonstration projects may also provide additional data to aid quantitative analyses. In addition to revealing true adoption rates, comparing outcomes across TTPs could also provide insight into what program processes perform better than others.
- Interviews with funding owners, users, criteria managers and industry personnel, in addition to transition managers, would provide a deeper insight into the cases and reveal more about interactions between communities of practice and their impact on technology adoption.

LIST OF REFERENCES

Adametz, J. J., Groesbeck, D. E., & Quibilan, R. (2016). *Navy strategy for cybersecurity of industrial control systems: Analysis and recommendations.* (Executive MBA Capstone Project Report) Monterey, CA: Naval Postgraduate School.

Adams, B. J., & Hartner, C. C. (2017). *Cyber-defense return on investment for NAVFAC energy technologies.* (Master's thesis) Retrieved from http://hdl.handle.net/10945/56728

Allen, T. J. (1977). *Managing the flow of technology.* Cambridge, MA: Massachusetts Institute of Technology Press.

Assistant Secretary of Defense for Research and Engineering. (2011). *Technology readiness assessment guidance.* Washington, DC: Department of Defense.

Augier, M., & Guo, J. (2017). The evolutionary nature of innovation and disruptive change: The interrelatedness of technology, leadership and organizations. In D. J. Watola, & A. Macintyre (Ed.), *International Military Leadership Association Workshop (IMLAW) - Technology And Leadership: International Perspectives,* 127–148. Kingston, Ontario: Canadian Defence Academy Press.

Chen, S.-C., Li, S.-H., & Li, C.-Y. (2011, December). Recent related research in Technology Acceptance Model: A literature review. *Australian Journal of Business and Management Research, Volume 1*(Issue 9), 124–127.

Cohen, M. D., March, J. G., & Olsen, J. P. (1972). A garbage can model of organizational choice. *Administrative Science Quarterly, 17*(1), 1–25.

DOD Small Business Innovation Research Program "About." (2018, February 27). Retrieved from USD (AT&L): https://www.acq.osd.mil/osbp/sbir/about/index.shtml

Federal Acquisition Regulation Subpart 25.2 Buy American – Construction Materials (2018, April 3). Retrieved from https://www.acquisition.gov/far/html/Subpart%2025_2.html

Ferlie, E., Fitzgerald, L., Wood, M., & Hawkins, C. (2005). The nonspread of innovations: The mediating role of professionals. *Academy of Management Journal, 28*(1), 117–134.

Gaughen, C. D., Pendleton, D. E., & Zarate, D. A. (2010). *Zero VOC, coal tar free splash zone coating (SZC)—Final Report.* Port Hueneme, CA: Naval Facilities Engineering Command.

Government Accountability Office. (2004). *Geothermal energy: Information on the Navy's geothermal program.* Washington, DC: Author. Retrieved from https://www.gao.gov/assets/250/242616.pdf

Government Accountability Office. (2013). *Defense technology development: Technology transition programs support military users, but opportunities exist to improve measurement of outcomes.* Washington, DC: Author.

Govindarajan, V., & Trimble, C. (2012). *The other side of innovation: Solving the execution challenge.* Boston: Harvard Business School.

Hage, J., & Meeus, M. T. (2009). *Innovation, science, and institutional change: A research handbook.* Oxford: Oxford University Press.

Hekman, D. R., Steensma, H. K., Bigley, G. A., & Hereford, J. F. (2009). Effects of organizational and professional identification on the relationship between administrators' social influence and professional employees' adoption of new work behavior. *Journal of Applied Psychology, 94*(5), 1325–1335. doi:10.1037/a0015315

Joint Capability Technology Demonstration Program Overview. (2018, February 27). Retrieved from USD (AT&L): https://www.acq.osd.mil/ecp/PROGRAMS/JCTD.html

Kingdon, J. W. (2003). *Agendas, alternatives and public policies* (2nd ed.). New York, NY: Longman.

Kudo, R. T. (2010). *NoFoam system for automotive fire apparatus vehicle foam discharge checks.* Port Hueneme, CA: Naval Facilities Engineering Command.

Kudo, R. T. (2011). *NoFoam system technology for aircraft hangar fire suppression foam system - final report.* Port Hueneme, CA: Naval Facilities Engineering Command.

Leewright, C. K. (2012). *A cost-benefit analysis of the Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS).* (Master's thesis) Retrieved from http://hdl.handle.net/10945/17400

Lomi, A., & Harrison, J. R. (2012). The garbage can model of organizational choice: Looking forward at forty. *Research in the Sociology of Organizations, 36*, 3–17. doi:10.1108/S0733-558X(2012)0000036004

Mathieson, K. (1991). Predicting user intentions: Comparing the Technology Acceptance Model with the theory of planned behavior. *Information Systems Research, 2*(3), 173–191.

Miyagawa, F. (2017, August). *Real world design challenges.* Presented at the Society of American Military Engineers Joint Engineer Training Symposium. Retrieved from http://samejax.org/images/downloads/resiliency__2_microgrids_miyagawa_.pdf

Nahavandi, A., & Malekzadeh, A. R. (1999). *Organizational behavior: The person-organization fit.* Upper Saddle River, N.J.: Prentice Hall.

National Research Council of the National Academies. (2004). *Accelerating the technology transition: Bridging the valley of death for materials and processes in defense systems.* Washington, DC: The National Academies Press.

Naval Facilities Engineering Command. (2015). *Technology transition final publication - Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS).* Port Hueneme, CA: Author. Retrieved from https://energy.gov/sites/prod/files/2016/03/f30/spiders_final_report.pdf

Naval Facilities Engineering Command. (2018). *Navy and Marine Corps facility query report* [Database]. Retrieved from https://fres.cnic.navy.mil

Park, C., Kim, H., & Yong, T. (2017). Dynamic characteristics of smart grid technology acceptance. *Energy Procedia, 128*, 187–193.

Plieth, H., Habicht, H., & Möslein, K. M. (2013). Agents in organizational innovation communities: The wind of change. *XXIV ISPIM Conference—Innovating in Global Markets: Challenges for Sustainable Growth* (pp. 1–16).

Pressman, J. L., & Wildavsky, A. (1984). *Implementation: How great expectations in Washington are dashed in Oakland.* Berkeley: University of California Press.

Ram, S., & Sheth, J. N. (1989). Consumer resistance to innovations: The marketing problem and its solutions. *The Journal of Consumer Marketing, 6*(2), 5–14.

Regnier, E., Barron, R. W., Nussbaum, D. A., & Macias, K. (2017). Stakeholder and process alignment in Navy installation technology transitions. *Defense AT&L January-February 2017*, 9–12.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Salem, A., & Gallenson, A. (2014). *A study of human behavior & operational energy: Analysis and recommendations for the Marine Corps to increase its operational reach.* (Faculty Research) Retrieved from http://hdl.handle.net/10945/44731

Saukkonen, N., Laine, T., & Suomala, P. (2017). How do companies decide? Emotional triggers and drivers of investment in natural gas and biogas vehicles. *Energy Research and Social Science*, *34*, 49–61. doi:10.1016/j.erss.2017.06.005

Sovacool, B. K., Kivimaa, P., Hielscher, S., & Jenkins, K. (2017). Vulnerability and resistance in the United Kingdom's smart meter transition. *Energy Policy, 109*, 767–781.

Stephenson, J., Barton, B., Carrington, G., Gnoth, D., Lawson, R., & Thorsnes, P. (2010). Energy cultures: A framework for understanding energy behaviours. *Energy Policy, 38*, 6120–6129. doi:10.1016/j.enpol.2010.05.069

Van de Ven, A. H. (2017). The innovation journey: You can't control it, but you can learn to maneuver It. *Innovation: Organization & Management, 19*(1), 39–42. doi:10.1080/14479338.2016.1256780

Yin, R. K. (2009). *Case study research: Design and methods.* Thousand Oaks, CA: Sage Publications.

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