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Analysis of the Factors that Correlate with Transition Outcomes of Commercial Technology Prototype Projects

Matthew D. Schoemaker

AN ANALYSIS OF THE FACTORS THAT CORRELATE WITH TRANSITION OUTCOMES OF COMMERCIAL TECHNOLOGY PROTOTYPE PROJECTS

THESIS

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Abstract

A key metric of success for Department of Defense (DoD) Research and Development organizations is the ability to "transition" technologies and prototypes. Office of the Undersecretary of Defense for Research and Engineering (OUSD R&E)'s prototyping guide shows successful transition pathways come in the forms of transition to operational use, rapid fielding, existing program adoption, or a new acquisition program (2018). There are many factors that occur throughout a prototype project's lifecycle that impact the likelihood of transition. These factors include both qualitative and quantitative factors. Limited research has been performed, past the best practice considerations, of what factors impact transition of prototyping efforts. This research evaluates commercial technology prototyping projects to identify the project characteristics and factors that correlate with transition success. The research setting is DoD's commercial product prototyping organization, the Defense Innovation Unit (DIU). The findings show that beyond technology success, the resources of time and money correlate with transition success, as well as stakeholder commitment and consistency, project execution and transition market factors.

Acknowledgments

I would like to express my sincere appreciation to my thesis advisor, Lt Col Amy Cox, and the members of the thesis committee for providing feedback and guidance in the completion of this research. Additionally, I'd like to thank Defense Innovation Unit for affording me the time, opportunity, and access to perform the research. Lastly, I'd like to thank my wife for supporting me in the pursuit of this thesis effort.

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I. Introduction

The United States Department of Defense (DoD) seeks to maintain key technological advantages in an era when commercial research and development spending and technology growth has outpaced the DoD. The National Defense Strategy states "The fact that many technological developments will come from the commercial sector means that state competitors and non-state actors will also have access to them, a fact that risks eroding the conventional overmatch to which our Nation has grown accustomed" (2018, p. 3) Rather than seek to lead in all aspects, one tactic is to benefit from the investments and innovations of others; to be a fast follower. To combat the loss of its technological overmatch, the DoD needs to become a fast follower of commercial technology, rapidly prototype and adopt those that can have military utility.

The task of transitioning prototyped technologies into the DoD falls upon a multitude of organizations that use various strategies. DoD's prototyping guide shows successful transition pathways in the forms of transition to operational use, rapid fielding, existing program adoption, or a new acquisition program (2018). Examples of prototyping organizations transition rate claims include DoD's Rapid Innovation Program of 50% (GAO, 2015), Defense Innovation Unit (DIU)'s success rate of 23% in 2019 (Maucione, 2019) and U.S. Air Force Small Business Innovative Research Projects transition rate of 8% (Rask, 2018). To become fast followers of commercial technologies, the DoD needs to ensure that successfully prototyped technologies can bridge the gap, commonly referred to as the "valley of death," from development and prototyping to sustained acquisition.

Defense Innovation Unit (DIU) is DoD's commercial technology prototyping organization with a mission to prototype best of breed commercial technologies to assess their military utility and transition them into sustained DoD capability. "DIU exists to ensure DoD has a pathway to rapidly prototype, modify, and field the best commercial technologies that solve national security challenges" (DIU, 2019, p.4). Leveraging commercial investments in technology development, DIU acquires and demonstrates defense applications of proven & viable commercial technologies (DIU, 2019). Unlike technologies that are under development, the commercial technologies DIU prototypes have been proven and validated in commercial operations.

This research finds that only 15% of DIU transition failures are attributable to technology performance. For DIU to assess and plan for the risks associated with prototype transition, a thorough understanding of the factors beyond the technology risks is needed. This research seeks to identify these prototype project factors that correlate with the likelihood of transition to improve project diligence, planning and transition outcomes.

1.1 Problem Statement

DIU, and the greater DoD, needs to gain further understanding of the challenges in transitioning successfully prototyped commercial technologies to sustained defense capability. DIU currently evaluates prototype projects through a Project Decision Board which, according to its 2018 annual report, leverages the Heilmeir Catechism, "a set of critical questions developed by DARPA to assess proposed research programs to select new projects". DIU's diligence factors for the board include: 1) Financial & Organizational Information, 2) DoD Problem, 3) Proposed Solutions, 4) Rough Order of Magnitude, 5) Customer Commitments, 6) Commercial Market Analysis, 7) Project Timeline, 8) Mission Impacts and Measures of Success, 9) Transition Potential and Strategy, 10) Draft solicitation language. The information provided in these categories is assessed to decide whether or not to execute a specific project. The assessment criteria is informed by best practice decision making, but there has not been formal reflection and empirical research into completed projects and what factors correlate with the transition outcomes of these projects.

This research identifies the DIU prototype project characteristics and factors that correlate with the likelihood of successfully transitioning commercial technologies. DIU's transition rate in 2019 was 23%; there are prototyping dollars and investments that are not leading to sustained capabilities. The overarching objectives of this research is to identify project characteristics and factors that are significant in the success or failure of project transitions so DIU can better select and manage projects.

1.2 Research Objectives

1) Identify characteristics of DIU prototype projects that correlate with transition success.

2) Provide recommendations for improving prototype project selection and planning at DIU to improve awareness of factors that correlate with transition success.

1.3 Investigative Questions

What pre-award and post-award factors correlate with technology transition likelihood?

To what degree do the following factors correlate with transition?

- Resourcing
- Technology Vendor Type (Large or Small Business, traditional or non-traditional DoD Vendor, etc.)
- Technology (Space, Cyber, Artificial Intelligence, Autonomy, Human Systems)
- DoD Partner (i.e. which Military Service Branches and Agencies)
- People Commitment
- Project Execution
- Transition Market

1.4 Methodology

Chapter three provides an in-depth description of the methodology, but a summary of the approach is provided in Figure 1 and the following description:

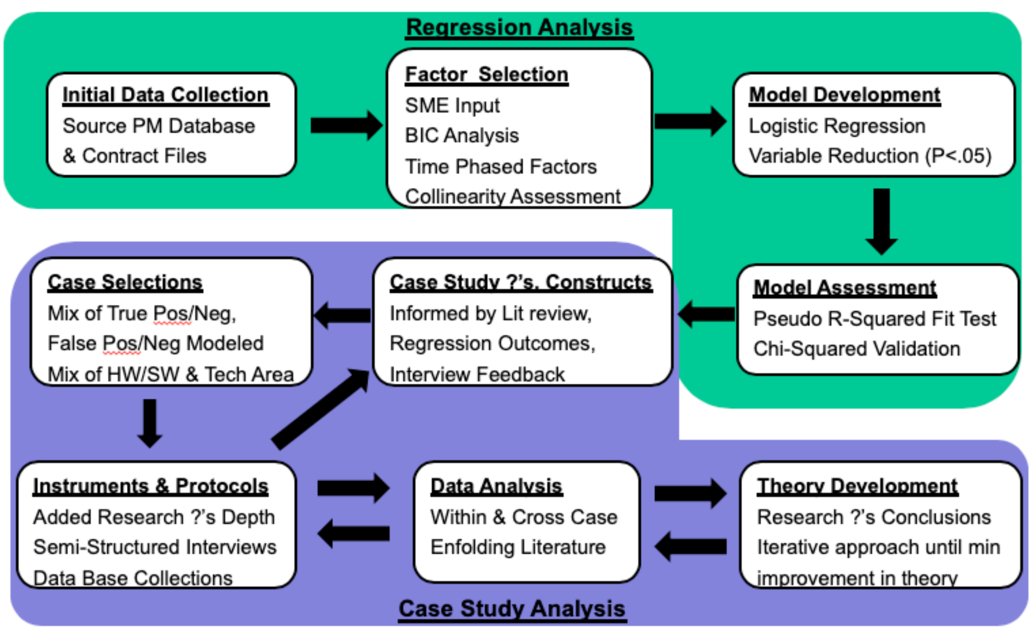

Figure 1. Regression Analysis & Case Study Research Methods Flow Chart

Phase I: Data Set Preparation

- Identification of pertinent project characteristic data that may impact transition based on feedback from DIU subject matter expertise
- Data collection from DIU program management and contract resources
- Data selection and reduction to projects that are completed and were awarded following common DIU prototyping procedures

Phase II: Regression Analysis of DIU Prototype Project Transition Data

- Model data set preparation for 3 models for knowledge at time of award, during execution, and at project completion
- Goodness of fit assessments for initial independent variable selection
- Collinearity Assessment
- Model formulation
- Dependent variable assessment for significance to transition outcome
- Model assessment of project factors significance on transition outcome variability

Phase III: Developing Theory from Case Study Research

- Defining further research questions and initial theoretical constructs
- Selecting cases, focusing on interesting cases from Phase II
- Crafting instruments and protocols, which includes project management data aggregation and subject matter expert interview data collection methods
- Iterative approach of collection and analysis to further define theory
    - Within-case analysis for preliminary theory generation

   - Cross-case analysis for evidence of divergent or convergent patterns
- Shaping hypothesis, identifying replication across cases and finding evidence behind the “why’s” for each construct to build internal validity
- Enfolding literature as a comparison with literature view points
- Finalizing theory

1.5 Limitations & Assumptions

This research seeks to identify factors in the setting of DIU prototype projects that correlate with commercial technology transitions from prototyping to sustained capability. The study includes key assumptions and limitations which guide and bound research development. Key assumptions and limitations include: 1) only DIU completed prototypes are considered for the study, 2) only DIU brokered transitions are considered, 3) all data gathered is accurate and complete, 4) interview responses are assumed accurate and truthful, and 5) organizational factors such as change in leadership and focus are understood limitations of environmental controls and decisions in these projects.

The first limitation in the research is there is a limited set of data available to model and evaluate the factors of DIU project transition. The data set was collected Dec 2019, and only 58 prototype projects have been completed in DIU’s 4 year history. DIU has over 60 projects currently in the prototyping phase. Projects in prototyping will not be included in the study as it is still to be determined if they will be successful in transitioning. The analysis and findings should be continually updated and re-evaluated as projects complete after this study to ensure theory validity.

U.S. Government Accountability Office (GAO) (2015) identified a limitation that is common across science and technology organizations: inability to track and to determine transitions post prototype completion. This study's definition of transition focuses on transition in the form of contracts, defined as occurring when DoD, outside of the prototyping organization, allocates budget or assumes management of a capability that the prototyping organization assessed. A transition could, by this definition, take place by various means including: the company being awarded a defense contract without DIU's knowledge, the capability being part of a subcontract on another government contract with a different prime vendor, or various other avenues of technology transition and adoption. The data set available only maintains data on transitions that occur directly due to prototyping efforts, and does not have the ability to identify when transition occurs without the organizations deliberate involvement.

The first assumption declared for this research is that interview responses are assumed to be truthful and accurate. A concern about interviewing individuals about their past feelings is hindsight and skewing to meet the intent of the study. Campbell and Stanley provide that in a retrospective pretest, "the probable direction of memory bias is to distort the past attitudes into agreement with present ones, or into agreement with what the tenant has come to believe to be socially desirable attitudes" (1963). This is an understood limitation of this effort. Campbell and Stanley also provide that though a pretest is most desirable, retrospective pretests are still significant contributors to experimentally oriented science and are still a useful tool (1963). The interview responses were received with an understanding of potential bias, but response accuracy was confirmed through triangulation with multiple data sources.

A second assumption for the research is the completeness and accuracy of the project data. Though a repository of recorded project data exists for DIU projects, this data was individually input and recorded with limited peer reviews. This research assumes that the data is complete and accurate. Data accuracy was ensured through the data consolidation phase by interviewing the project teams, gathering missing information from previous program managers, and cross references with contract files.

Lastly, an environmental control limitation that exists in the research is that DIU went through rapid reorganization and refocusing in respects to business operations and transitions throughout the lifetime of these projects. Leadership perspectives on risk tolerance, the focus on transitioning projects, the challenges of adoption of Other Transaction Authority concepts, and other factors may impact how individuals felt about projects and transitions. These impacts of environmental changes are expected to become evident in the research into how the individual cases addressed transition throughout these different periods.

1.6 Implications

The expected results from this study are a better understanding of factors that correlate with transitioning prototyped commercial technologies, better decision making prior to project initiation, and improved planning and management throughout the prototyping effort. With the DoD's investment of $21.984 billion for Research, Development Test and Evaluation of Advanced Component Development & Prototyping, it is critical that decision makers are aware of what factors are correlated with transition and technology adoption. This research provides the basis for understanding of these factors.

Additionally, the expected results from this study are enhanced decision making tools for DIU leadership. DIU's project total, as of Dec 2019, was 120 projects, with 62 in execution and 58 that have completed prototyping. Of the 58 completed projects, 19 have successfully transitioned by follow on contract. As OSD's acquisition arm to reach Silicon Valley technology with a goal of increasing the adoption of commercial technology into the National Defense Industrial Base, DIU seeks to transition successful prototyped projects to sustained DoD capability. To improve the current rate of successful transitions, a better understanding of prototype project factors that correlate with transition is required. This research provides awareness into what factors are significantly correlated with the transition outcomes of DIU prototyped projects.

1.7 Preview

The research investigates which factors are significant to transition likelihood in the prototyping of commercial technologies. The Defense Innovation Unit (DIU), as the DoD organization responsible for commercial technology prototyping, offers a setting for identifying these factors and evaluating their impact on prototyping projects and their transitions. The research uses regression analysis of DIU program management data and focused case studies to develop theory to find factors correlated with transition outcomes.

This research follows a standard scholarly path. Chapter two provides a literature review which introduces the setting of the research and the current state of technology transition factor theories and approaches. The first part of chapter two introduces DoD acquisitions. The second part introduces DIU, use of Other Transaction Authority for prototyping, and its approach to project diligence, execution, and transitions. The last part provides background on the "Valley of Death" for technology transitions and the research and knowledge to date on technology transition factors.

The third chapter provides the research methods. The first part of the research was performed using methods of regression model development as in Ott and Longnecker's "An Introduction to Statistical Methods" (2016). The second part of the research was performed following Eisenhardt's "Building Theory from Case Study's Research" (1989). The use of two methods provided additional richness of the research findings, as well as grounding of the theory outcomes.

The fourth chapter provides the results and analysis. The regression model development analysis shows how variables significant to predicting transition were identified and how much of the variability of transition likelihood could be described by these factors. The case study analysis provides the development of theory around additional transition outcome factors identified through the literature review, interview responses, and cross-case analysis for pattern identification.

Lastly, the final chapter provides the research conclusions. First, it provides answers to the research's investigative questions. Second, it provides the implications and significance of the research's findings. Third, it provides recommendations for action based on the research. Last, it provides recommendations for future research.

II. Literature Review

2.0 Chapter Overview

This chapter provides insight into the technology transition challenge in the DoD and at DIU. This insight is accomplished by describing DoD acquisitions, the DIU as the setting for this research, the "Valley of Death" for technology transition, and descring the current understanding of factors in prototype projects that impact transition likelihood.

2.1 Defense Acquisitions and Prototyping

The bulk of the weapons systems, products and services that the DoD needs are procured from external vendors through the DoD's acquisition system. The DoD's acquisitions system "exists to manage the investments of the United States in technologies, programs, and product support necessary to achieve the national security strategy" (DFAR, 2018, p. 1). The acquisition system encompasses the tools and methods to procure products and services of varying technological complexities to accomplish DoD's missions.

The acquisition workforce looks to the National Security Strategy and the National Defense Strategy (NDS) to guide how to spend the DoD's budget. The 2018 NDS has an objective to streamline rapid and iterative acquisition approaches from development to fielding in which it states that "Prototyping and experimentation should be used prior to defining requirements," for the Department to "quickly respond to changes in the security environment and make it harder for competitors to offset our systems" (p. 11). The call to prototyping provides research and engineering organizations the direction to be agile and adaptive to meet national security needs.

Prototyping in defense acquisitions has an end state goal of "transition." According to DoD's Prototyping Guidebook, prototype success is measured by whether or not the project generates the information necessary to support a transition pathway decision (2018). The guidebook also lists different transition pathways including when the prototype is:

1) Discarded
2) Returned to the technology base for further development
3) Transitioned to operational use
4) Transitioned to rapid fielding
5) Integrated into a program of record
6) Transitioned technology into a new acquisition program

The transition pathways with prototype outcomes that meet the NDS's goals of delivering capability in quick response of national security needs are transition paths three (3) through six (6).

2.2 Defense Innovation Unit, Other Transactions, and Prototype Transitions

Defense Innovation Unit Experimental (DIUx), now named Defense Innovation Unit (DIU), is known as "DoD's Silicon Valley outpost." It has the responsibility of sourcing dual use commercial technologies for prototyping in military use cases and transitioning to sustained military capability. Through DIU, the DoD is able to act as a fast follower and adapt commercial technology investments to meet defense specific needs.

DIU’s Annual Report (2017) states “It is DIUx’s mission to lead DoD’s break with past paradigms of military-technical advantage to become fast adapters -- as opposed to sole developers -- of technology, integrating the advanced commercial capabilities necessary for strategic advantage” (p. 2). To complete this mission, DIU must source commercial technologies that can solve DoD problems, prototype them in the military use cases, and successfully transition the technology. Rather than develop novel technologies, DIU seeks to adapt them.

DIU’s acquisition and business model is to prototype commercial technologies with a DoD partner and typically leverage DoD partner funds. DIU developed its Commercial Solution Opening (CSO) contract process to execute prototype projects of commercially available technology with DoD partners to solve national defense problems (DIU, 2018). The CSO acquisition process was specifically designed to leverage the Other Transaction Authority (OTA) statute to quickly and effectively award prototype contracts to non-traditional DoD vendors.

OTA is used to streamline acquisition processes and provide “the flexibility necessary to adopt business practices that reflect commercial industry standards”, which provides the Government “access to state-of-the-art technology solutions from traditional and non-traditional defense contractors” (OUSD A&S, 2018, p. 4). OTA’s utility for accessing commercial vendors and transitioning technologies came about through the 2016 and 2017 NDAA’s expansion of 10 U.S.C. 2371 parts (b) and (f), titled Other Transaction Authority for Prototyping and Production respectively. OTA allows for the award of non-Federal Acquisition Regulation (FAR) based agreements to non-traditional DoD vendors. The key expansion to OTA was in part (f), which provided the ability to award non-competitive production contracts or agreements based on a competitively awarded prototype OTA agreement and prototype success. DIU's 2018 Annual Report asserts "This enables commercial innovation to survive the "valley of death" that often separates newer capabilities from our warfighters." Thus, the production without further competition opportunity is the vehicle which enables DIU to ease transition to sustaining acquisition organizations, and facilitate the vaulting of the technology "valley of death".

DIU's definition of successful transition and tracking metrics align well with the intent and provisions of these OTA statutes. DIU states that "We measure our performance based on our ability to successfully operationalize commercial solutions and deliver them to a DoD customer for transition via production OT agreements or other appropriate contract vehicles" (DIU, 2018, p. 6). Therefore, successful transition by DIU's standards occurs either when DoD (outside of DIU) allocates budget or when a DoD partner outside of DIU assumes management responsibility of a capability DIU prototyped.

DIU has a goal of transitioning the prototypes it successfully completes into sustained DoD capability. Even after prioritizing transition and assessing all of these factors the valley of death is still a significant challenge. DIU, as found at the time of this report, has had a 32.7% transition success rate. At the time of this research, DIU had not performed a formal assessment to determine the factors correlated with transition success.

2.3 DoD Acquisitions Transitions and the "Valley of Death"

Technology transition challenges can occur when technology vectors change or the pace of development outstrips budgetary and stakeholder alignment. Organizational factors compound this alignment challenge; we are organized with divides between Research and Engineering (R&E) communities and the Acquisition and Sustainment (A&S) communities. Susan Blume of Defense News highlights that "The planned AT&L split will place oversight responsibility for development of advanced technologies and procurement of those technologies in separate organizations. Doing so could compound the existing challenges of turning a promising technology into a full-rate production program, colloquially known as the valley of death" (2017). The DoD has an ongoing challenge to ensure investments made in Research and Development turn into Acquisition and Sustainment programs, thus bridge the "valley of death".

2.3.1 Current Understanding of Prototype Transitions Factors

A common factor associated with technology transition is technical maturity. Technology Readiness Levels (TRL) and Manufacturing Readiness Levels (MRL), are scales that were developed to assess the technical maturity of systems and technologies and their readiness for integration and production. Both scales range from low maturity or readiness (1) to high (9), shown in Figure 2.

Phase	TRL	Hardware	Software
Research	1	Basic principles	
	2	Concept and application formulation	
	3	Concept validation	
Development	4	Experimental pilot	
	5	Demonstration pilot	
	6	Industrial pilot	
Deployment	7	First implementation	Industrialization detailed scope
	8	A few records of implementation	Release version
	9	Extensive implementation	

Manufacturing Readiness Level (MRL)

Phase	MRL	State of Development
Phase 3: Production Implementation	9	Full production process qualified for full range of parts and full metrics achieved
	8	Full production process qualified for full range of parts
	7	Capability and rate confirmed
Phase 2: Pre production	6	Process optimised for production rate on production equipment
	5	Basic capability demonstrated
Phase 1: Technology assessment and proving	4	Production validated in lab environment
	3	Experimental proof of concept completed
	2	Application and validity of concept validated or demonstrated
	1	Concept proposed with scientific validation

Figure 2. Technology Readiness Level(TRL) & Manufacturing Readiness Level(MRL)

Though a system or capability has been demonstrated in a relevant environment, remaining costs and risks to cross the valley of death continue to be a barrier. Even if the technical risk is low (e.g. the new invention will work as intended), there is still an enormous amount of cost and associated risks before successful implementation on or as a product. (Newman, n.d.). Technologies, though proven in a representative or comparable environment, including highly successful in commercial offerings, may still have risks associated in a new use case.

The DoD's technology "valley of death" exists for many reasons in addition to technology success. These barriers and challenges can include funding structures, risk averse cultures, competing priorities, budget timelines, and synchronization with acquisition programs (GAO, 2017). This shows that a project is likely to fall into the "valley of death" without the right technology success, proper timing and type of funding for the capability, willing partners to accept risks of prototypes, commitment and alignment from the stakeholders, and acquisition planning and synchronization.

2.3.2 Resourcing in Technology Transitions

Appropriate resourcing is a key to success both for technology development and prototype transition. Clayton Christensen's *The Innovator's Dilemma* offers that customers control the resource allocation process and states that "Only those new product development projects that do get adequate funding, staffing, and management attention have a chance to succeed; those that are starved of resources will languish" (2016). Projects success relies on adequate funding, which is directly tied to customer demand. In a DoD setting, the R&E transferring organization requires the demand and resourcing of the technology A&S organization.

Due to these challenges posed by transition the DoD has developed metrics to assess confidence in and readiness of technology transitions. A common factor identified in these metrics is resourcing. Two of these transition metrics developed within the DoD include the Transition Confidence Levels (TCL) and the Adoption Readiness Level (ARL). The TCL was developed by Davis and Ballenger of United States Special Operations Command (USSOCOM) Acquisition Technology & Logistics (AT&L). The Adoption Readiness Levels (ARL) was developed by the Naval Postgraduate School (Barron, Regnier, Nussbaum & Macias, 2017). Each tool provides a transition planning metric similar to the well established Technology Readiness Level scale; projects receive higher assessments as readiness is improved and risk is reduced. The metrics and associated scale for TCL and ARL are shown in Figure 3.

Level	Characteristics
9	• Transition to PEO funding and management completed • Transition After Action Report and storyboard documented on S&T portal • Transition success report to AT&L
8	• Signed transition agreement between PM and S&T • Transition funding committed
7	• Integration strategy defined • Transition cost estimate complete • Potential funding sources identified
6	• Transition technical goals approved by PM, S&T • Transition schedule estimate developed • Project included in PM plans as a potential source
5	• Expressed interest from PM office • Active communication with named PM contact
4	• Target PMs briefed and provided progress updates • Key transition stakeholders named • Relevant programs named
3	• Specific project technical goals established • Target acquisition programs identified • Potential transition stakeholders identified
2	• Project initiated • TRL goals established (baseline)
1	• Working Group interest expressed • Active tech discovery • Acknowledged gap

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 3. SOCOM TCL (Davis & Ballenger, 2017) & Navy ARL (Barron et al, 2017)

TCLs and ARLs both increase when resourcing is identified and committed. Further, codified stakeholder commitment and increases in collaboration also improve TCLs and ARLs. Specifically, improvements in collaborations between S&T organizations and acquisitions and sustainment organizations (ex. A&S Program Executive Office (PEO) or Operations and Sustainment (O&S) organizations) can improve a programs rating. Funding, commitment, and collaboration are all important factors in transition in these assessment metrics.

2.3.3 Collaboration & Commitment in Technology Transitions

The two factors most highlighted in the TCL and ARL metrics are S&T and PEO/O&S communication and financial commitments. Funding commitment confidence increases as transition cost estimates are completed, potential funding sources are identified, funding is committed, and lastly a funded transition occurs. Communications mature in order of identification of the transition partner offices, briefings and active communication, receiving office commitment to transition, transition agreement, and lastly a completed transition. This further shows that technology transition confidence, based on these scales, is determined by how well resourced and how actively communicated projects are between S&T and A&S organizations and the stakeholders.

To further add to the importance of communication, the DoD's Manufacturing Readiness Level guidebook highlights "collaboration and coordination between research organizations and acquisition communities is essential to effective transition and bridging the valley of death" (DoD MRL, 2012). Defense Acquisition University (DAU) shows in Figure 4 how the "valley of death" resides between the science and technology organizations and system program offices, and the need to utilize continuous communication in order to align programs and scheduling of integration and budgeting to "Bridge the Valley of Death Gap" (DAU, 2007)

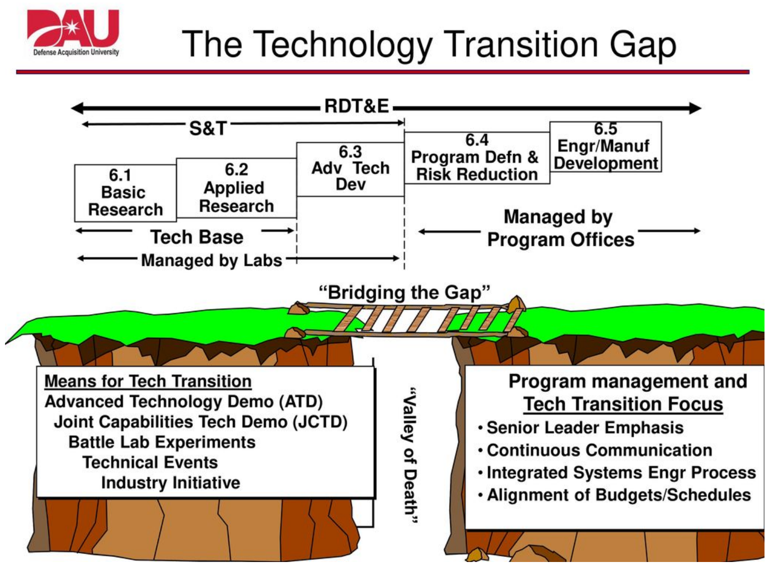

Figure 4. DoD Acquisitions milestone chart and the Valley of Death. (DAU, 2007).

Additionally, in a DoD report to Congress on the state of Technology Transition offered "that chasm, commonly referred to as the 'valley of death,' can be bridged only through cooperative efforts and investments by both communities" (2007). Cooperation and communication, as well as resource allocation, are once more identified as being required by both sides of technology development and acquisition and sustainment to ensure transition of prototypes.

Finally, the U.S. Government Accountability Office (GAO) conducted multiple studies of technology transitions from the Defense Advanced Research Projects Agency's (DARPA) transition of technologies in the DoD. GAO (2015) identified four factors that contributed to transition success:

1) Military or commercial demand for the planned technology

2) Linkage to a research area where DARPA has sustained interest

3) Active collaboration with potential transition partners

4) Achievement of clearly defined technical goals

Adding to research and policy from SOCOM, NPS and DAU (Davis and Ballneger, 2017; Barron et al, 2017; DAU, 2007), we once more see that demand and active collaboration are significant factors in technology transition success.

2.3.3 Project Champions in Technology Transitions

The literature indicates collaboration between transition partners is correlated to transition success; while this collaboration is important, it's also necessary to understand who is collaborating. Another aspect that impacts technology transition is the individual people in the projects and their role-based activities. To understand technology transition from a role-based perspective, it is important to identify the relevant roles, their impact on resourcing, and who is best suited for the roles.

Technology transition is more likely when key personnel are in place to shepherd technology across the "valley of death". According to Markham et. al (2010), these key personnel include a Champion to adopt and advocate for a project, a Sponsor to approve and resource the project, and a Gatekeeper to evaluate the project and make decisions on its future. Persons serving effectively in these roles have been shown to have a bridging effect relative to the "valley of death." These roles can be combined into the responsibilities of one or two individuals. These roles and their specific activities and interactions are represented in Figure 5.

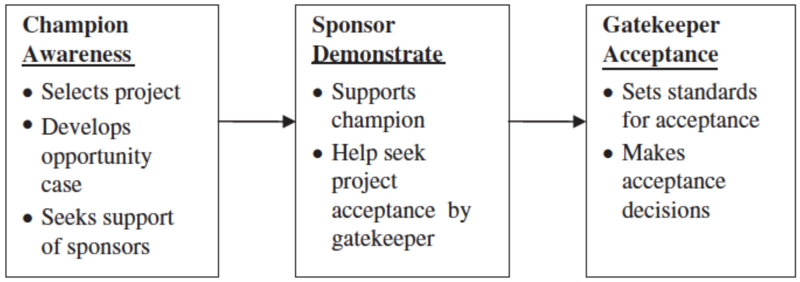

Figure 5. Relationship between Transition Role Players (Markham, et al., 2010)

The literature also identified that rank and responsibility need to be appropriately aligned with the role in order to adequately support the transition. Stakeholders in DoD and Commercial companies can vary in rank, from low to high in their organization. Christensen offers that executive level sponsorship receives first attention in customer alignment, but the non-executive level individuals sponsor ideas and are actionably responsible for the ideas and champion them in their organizations (2016). This suggests that when identifying a project champion, it is often a non-executive level individual who will own this role and gain sponsorship and resources.

2.3.3 Turnover in Defense Acquisitions and Project Success

Individuals involved in projects have significant impacts on the transition outcomes. Personnel turnover is a characteristic intertwined with prototype project stakeholders. Lack of consistency in stakeholders is a well-documented problem in DoD acquisitions history and reform policies. Military officer's program management assignments are frequently brief "due to the established military policy of assignment rotations", and these rotations "often came at critical points in acquisition programs" while leaving little or no opportunity to prepare program manager successors (Fox, 2011,

p. 66). These turnovers drove Congress to pass Defense Acquisition Reform in 1984 to establish a minimum 4-year tenure for Program Managers (Fox, 2011). Turnover has been identified as a problem that can occur in defense acquisition programs at large.

Turnover is also identified in literature as a signifier of commitment, or lack thereof, and is shown to be negatively correlated with project success. Allen and Meyer (1990) provide that “common to all the conceptualizations of commitment found in the literature is a link with turnover; employees who are strongly committed are those who are least likely to leave the organization” (p. 1). Additionally, empirical evidence shows that technology projects with high turnover are less likely to succeed than those with lower turnover (Hall, Beecham, Verner & Wilson, 2008). Thus, turnover of stakeholders is negatively correlated with commitment and transition success.

2.3.4 Acquisitions Planning and Commitment in Technology Transitions

Acquisitions planning, alignment, and commitments are also key factors found in relation to transition successes. An assessment of factors leading to transition likelihood identified three of the key factors of transition as 1) strategic planning for market needs, 2) gated reviews to continually test for the feasibility of the technology, and 3) commitment of transition partners (GAO, 2006). Commercial companies “3M and Motorola require product line commitment to transition a technology” before they’ll commit funding resources to development phases (GAO, 2006, p. 18). To transition prototype technologies, the commercial best practice is to have a strong understanding of project commitments from the transitioning partners, and to make the decision of technology transition commitment early in development efforts.

The transition planning examples of 3M and Motorola also showed stakeholder alignment is an important transition factor. From a report on naval installation technology transition, "A common pitfall in demonstration projects is to wait too long to engage all relevant stakeholders, such as facilities engineers, technical approval authorities and maintenance technicians" (Barron et al., 2017). Aligning stakeholders to the goals of the project, and doing it early, is another best practice and factor in technology transitions.

Tools for measuring stakeholder alignment and planning include TCLs, ARLs and other tactical tools. A GAO report on technology transition offered additional effective tools for transition communication and commitment include Technology Transition Agreements (TTA), Relationship Managers, DoD programs to aid transition, and metrics of transition (2006). Two of these additional tools captured were TTAs and relationship managers. TTA's document and formalize the expectations of the stakeholders in the transitioning of the technology and signifies their commitment and resource planning for the project. Relationship Managers, used specifically by DARPA, draft transition strategies and manage relationships for technology prototypes and the transitioning acquisition organizations (GAO, 2006). The DARPA Relationship Managers develop a relationship to support communication, collaboration, and commitment in the transition process. TTA's and Relationship Managers goals are to show organizational commitment to transition as early as possible and maintain stakeholder communication and commitment to technology transition.

2.3.5 Transition Market in Technology Transitions

In addition to having a committed partner to help transition technologies, developing multiple transition partners and a larger transition market impacts the likelihood of transition. One best practice is aligning multiple transition partners, “at least two stakeholders who can serve as champions for your work”, because “with at least two to mitigate the effects of losing one (for instance, to military rotation)” (D’Amico et al., 2012). This aligns directly with DoD’s report to congress on technology transitions stating that for effective transition, “S&T manager must be a marketeer” (2007). Empirical research has also shown that technology transition managers must encompass many of the critical responsibilities of a marketer in industry (Csoma, 2010). The transition market and the active marketing of the technology has been identified as a factor in the success or failure of technology transitions.

2.4 Summary

Defense Acquisitions has long experienced the challenge of technology transitions from prototyping to sustained capability, known as the “Valley of Death”. DIU currently addresses this challenge through project decision board documents, though limited research has been done on which factors in the diligence are correlated with the transition outcomes. The areas in which transition factors have been identified in this literature review include technology success, resourcing, commitment and collaboration, transition planning, and transition market.

III. Methodology

3.0 Chapter Overview

The research was conducted as a two-step approach that includes a (1) statistical analysis of what factors known in DIU projects most correlate with prototype project transition, followed by (2) case study research to further develop theory and identify factors.

The first step was initial statistical research that was conducted as a phased approach. This phase loosely followed regression model formulation described by R. Lyman Ott and Michael Lognecker's "An Introduction to Statistical Methods & Data Analysis". Phase one included determining relevant data, gathering data and preparing the data for model development. The second phase developed regression models to evaluate which factors at contract award, during execution, and at completion, are significant predictors of transition outcomes. Phase three evaluated the overall model and how much of the transition likelihood variability was associated with the significant factors. The regression analysis findings in turn informed the selection of the case considered during the second step of this research.

The case study research was conducted by an approach similar to the tools provided by Kathleen Eisenhardt (1989). This investigation included semi-structured interviews and program data analysis to determine additional qualitative factors that impact transition outcomes. The responses and data were evaluated by within-case analysis, cross-case analysis, and literature review comparison to develop and ground the emerging theory.

The motivations behind the research is DIU's mission to increase the adoption rate of commercial technologies for military use. To increase adoption of commercial technologies, DIU's prototype projects need to transition to sustained capability. This thesis identifies characteristics in the projects that correlate with transition success. This identification will enable improved project decision board documents towards a goal of better understanding risk factors prior to project start.

3.1 Research Method

The availability of data and historical observations made empirical methods appropriate for the conducting of this research. Empirical methods include the posing of a research question or hypothesis and collecting data from actual projects or engineers to accept or reject the hypothesis, or answer the research questions (Patten, 2009). DIU has kept sufficient records that provide as a source of data from four years of projects for the quantitative portion of data collection. Interviews were completed with Project Managers or other individuals close to each project. This information was put through the rigors of regression analysis and case study theory development to investigate the research questions.

3.2 Research Setting

The setting for this research is completed DIU prototyping projects that were solicited and awarded under 10 U.S.C. 2371b Other Transaction Agreement (OTA) for Prototyping Authority. These projects include prototyping commercially vetted and viable companies and technologies for their military utility. Completed projects were chosen because they provide information that includes the results of the prototypes transition outcomes. Prototype projects awarded by utilizing the 10 U.S.C. 2371b statute projects were chosen because prototypes awarded under this authority follow DIU's standard contracting and prototyping model and have the opportunity for production awards without further competition as long as the prototypes were competitively awarded and are successful.

Within this setting, successful DIU prototype transitions are defined by the DoD Prototyping Guide that address via contract. Residual operational capability is another form of successful transition, but this form is too difficult to effectively track adoption and actual success. Transition therefore occurs when management of the DIU awarded prototyped capability is resourced and sustained by another DoD managing office by a procurement contract or agreement. Transition by this definition can occur by Production OTA, follow-on FAR based procurement contracts, or if the vendor's offering is provided in a subcontracting relationship to a procurement contract with a different prime vendor.

3.3 Regression Research Data Selection, Gathering, Cleaning

Initial data selection for the statistical analysis and investigation required identifying which independent variables helped uniquely identify the projects, and could also be predictors of project transition. According to Ott and Logngnecker, the steps to selecting variables requires knowledge of the problem area by (1) identifying the dependent variable being studied, and (2) sourcing individuals who could provide insight into the factors that affect it (2016). The individuals providing insight included subject matter experts and Program Managers at DIU.

Research data was sourced from the project files of 58 projects that DIU has completed since 2016. The effective use of two program management tools, DIU project data deemed to be of interest to transition by DIU SME's could be compiled to meet the research needs. This data included period of performance (PoP) of the project, obligated funds, DIU funding, type of DoD partner (Military Service Branch or Agency), type of vendor providing solutions (small or large business, non-traditional or traditional defense vendor, etc.), number of contract modifications, PoP changes from modifications, and obligated funds changes from modifications.

To combat missing or incomplete data, two program management tool data sources were compared against each other, providing data concurrence or conflict, missing information and anomalies. All information was confirmed or sourced through the respective contract documents for each of the projects to ensure completeness and accuracy.

3.4 Logistic Regression Analysis

Multiple regression provides this research with answers to which independent variables are statistically significant in predicting transition, and the variability in the dependent variable explained by the significant independent variables. The regression analysis was established as a time phased approach. Models were built for three time frames of knowledge including: 1) what is known at the beginning of a project, 2) what is learned during project execution, and 3) what is known at project completion. The factors associated with each time frame are included in Table 1. The prepared data for each case was then analyzed by multiple regression models.

Table 1. Factors included in Prototype Time Frames for Regression Modeling

Prototype Time Frame	**Unique Factors Included in the Models**	**Common Factors Included in the Models**
Pre-Award Prototyping	Original Pop, Original Funding	DIU Funding, Vendor Type, DoD Partner Type, Technology Type
Post-Award Prototyping	Original PoP, Original Funding, PoP modification, Funding Modification # of modifications	
Prototype Completion	Final PoP, Final Funding, Contract Modifications	

**Vendor Type includes the variables and combinations of small & large businesses, traditional & non-traditional DoD vendors, 1st time DoD vendors, Large business with cost sharing to meet OTA statute.*
** DoD Partner Type included the independent factors of U.S. Army, Navy, Marines, Air Force, Combatant Command, and/or 4th Estate partnership in prototyping.*
** Technology Type included separate factors of Artificial Intelligence, Autonomy, Cyber, Space and Human Systems*

The dependent variable of transition and the independent variables (Table 1), were analyzed through the regression model creation phases. According to Ott and Longnecker, the phases for performing multiple regression include selecting variables, formulating the model and checking model assumptions (2016). The same phases of model development were used for each model of time framed knowledge of prototyping.

3.4.1 Variable Selection

The independent variable selection phase was initiated by gaining subject matter expertise feedback in finding the original variable data set and was further complemented by the use of best subset regression tools and correlation assessments. Best subset regression tools are computer algorithms that provide the outputs of the best fitting regression equations from a set of independent variables. The algorithm identified the best fit according to Bayesian Information Criterion (BIC). Following this, multicollinearity was assessed via correlation matrices.

Bayesian Information Criterion (BIC) is the appropriate goodness of fit assessment for logistic regression, as both BIC and logistic regression follow a maximum likelihood estimation framework. BIC measures the error variance associated to the dependent variable by the predictor independent variable. BIC also provides penalties for unnecessary independent variables and model complexity. Selecting the model having the smallest BIC would give a model with predictors providing the best fit, while also penalizing models with extraneous or insignificant variables. The equation for calculating BIC is:

$$BIC_k = nlog_e\left(\frac{SS(Residual)}{n}\right) + klog_e(n)$$

Where:

SS(Residual) is the residual sum of squares from the model

n is the number of data values

k is the number of explanatory variables

The significant independent variables for modeling transition outcomes from the goodness of fit analysis were then assessed for multicollinearity. Independent variables that are highly correlated will have common variability and common error, making it difficult to separate how each variable is significant to the prediction of the dependent variable. “In most situations, any correlation over .9 or so definitely indicates a serious problem” (Ott & Longnecker, 2016). To assess and ensure that multicollinearity did not exist, the independent variables were put through a correlation matrix algorithm.

3.4.2 Formulating the Model

Formulating the model required identifying the appropriate type of regression to use for the variables, assessing the statistical relevance of the independent variables, and reducing them to where only variables significant to describing the dependent variable are included in the model. The regression model necessary for this setting needed to allow for multiple explanatory variables and a binary outcome dependent variable of transition or not. "The model often used to study the association between a binary response and a set of explanatory variables is given by logistic regression analysis" (Ott & Longnecker, 2016). With the dependent variable being a binary success or failure of transitioning, logistic regression modeling was most appropriate.

To assess which variables to include in the regression models, initial models for each time phase of knowledge (pre, during, post project execution) were created with all relevant independent variables from the variable selection section. The independent variables p-values were then assessed to determine their statistical significance to the dependent "transition" variable in the logistic regression model.

The variable's p-value is the test statistic used for significance tests of independent variables in the regression models. The p-value tests a null hypothesis that the independent variable has no effect on the model's prediction of the dependent variable. Therefore, a low p-value of less than .05 allows for the rejection of this hypothesis and the assertion that the variable has a significant effect on the outcome of the model. Variables that had a p-value greater than .05 were singularly removed and the regression model rerun until only significant variables with p-values less than .05

remained. The remaining independent variables are identified as being significant factors correlated with transition outcomes.

3.4.3 Assessing and Validating the Model

The next step was to assess the impact of the factors on the transition likelihood dependent variable. The model chosen was a logistic regression analysis model which utilizes a maximum likelihood method. The appropriate tool for assessing how much variability is described by the remaining independent variables is McFadden's Pseudo R-squared. This goodness of fit assessment takes the log-likelihood of the value containing no descriptive independent variables, just the intercept (LL(null)), and subtracts that from the log-likelihood of the model containing the independent variable predictors (LL(model)) and divide that by the LL(null). The higher the Pseudo R-squared value the more variability is being described by the predictors.

To ensure that the Pseudo R-squared value did not come about by chance, a p-value was calculated for the Pseudo R-squared. The p-value test statistic was calculated by extracting a chi-squared value from 2*(LL(model)-LL(null). This value was referenced to a chi-squared distribution table to provide the p-value for the model and confirm that the variability in transition outcomes described by the model was within a 95% level of confidence.

3.4.4 Model Development Outcomes

The model development process provides three outcomes relevant to determining factors which correlate with transition outcomes in DIU projects. The first of these is identifying predictor factors that are significant to the variability in modeling transition outcomes during each time phase of prototype projects. The second is identifying how much of the variability in transition outcomes can be associated to these factors. The last outcome of the model development provided modeled transition likelihoods for each project that were either consistent or inconsistent with the actual outcomes and are therefore deserving of further case study analysis.

3.5 Case Study Creation

Eisenhardt's method for building theory from case study was used for the continued empirical analysis. This research provides a phased and iterative approach that starts with research question development and case study selection, then data collection and analysis, and ends with research closure and theory outcomes. The phases of this method are described in detail in Figure 6.

Step	Activity	Reason
Getting Started	Definition of research question	Focuses efforts
	Possibly a priori constructs	Provides better grounding of construct measures
	Neither theory nor hypotheses	Retains theoretical flexibility
Selecting Cases	Specified population	Constrains extraneous variation and sharpens external validity
	Theoretical, not random, sampling	Focuses efforts on theoretically useful cases—i.e., those that replicate or extend theory by filling conceptual categories
Crafting Instruments and Protocols	Multiple data collection methods	Strengthens grounding of theory by triangulation of evidence
	Qualitative and quantitative data combined	Synergistic view of evidence
	Multiple investigators	Fosters divergent perspectives and strengthens grounding
Entering the Field	Overlap data collection and analysis, including field notes	Speeds analyses and reveals helpful adjustments to data collection
	Flexible and opportunistic data collection methods	Allows investigators to take advantage of emergent themes and unique case features
Analyzing Data	Within-case analysis	Gains familiarity with data and preliminary theory generation
	Cross-case pattern search using divergent techniques	Forces investigators to look beyond initial impressions and see evidence thru multiple lenses
Shaping Hypotheses	Iterative tabulation of evidence for each construct	Sharpens construct definition, validity, and measurability
	Replication, not sampling, logic across cases	Confirms, extends, and sharpens theory
	Search evidence for "why" behind relationships	Builds internal validity
Enfolding Literature	Comparison with conflicting literature	Builds internal validity, raises theoretical level, and sharpens construct definitions
	Comparison with similar literature	Sharpens generalizability, improves construct definition, and raises theoretical level
Reaching Closure	Theoretical saturation when possible	Ends process when marginal improvement becomes small

Figure 6. Process of Building Theory from Case Study Phases (Eisenhardt, 1989)

3.5.1 Research Questions

Research question definitions, as the first step of the case study, are constructs that are developed through prior literature, research and theory. The initial research questions for this case study were informed by the literature review and statistical analysis outcomes which provided factors of organizational and personal commitment, resourcing, and planning. The initial research questions included to what degree do the factors of resourcing, stakeholder commitment, acquisition execution and planning, and transition market correlate with transition outcomes. Following Eisenhardt's methods, the research questions evolved with the overlapping of data collection and analysis as well as the emergence of patterns in cross-case analysis.

3.5.2 Case Selection

The next step of the Case Study development was case selection. The cases were chosen from the outputs of the logistic regression modeling in the regression analysis phase of the research. Cases of interest include projects that were successful and likely to be successful, unsuccessful and likely to be so, unsuccessful but were likely to transition, and likely to transition but unsuccessful. This provided a deeper understanding of what occurred in the given prototypes beyond the quantitative metrics that led to true positive and negative results, as well as the false positive and negative results.

Additionally, completed projects incorporated in the case study were selected to ensure diversity and data availability. These criteria included a mix of hardware and software projects, a mix of technology portfolios, and availability of a PM to interview and data to investigate. This offered a sampling of projects which could provide insight into unique transition factors for the types of technologies, and also commonalities and patterns regardless of technology differences.

3.5.3 Crafting Research Instruments and Protocols

Crafting instruments and protocols is the third step in developing theory from case study. Data collection methods included gathering project data on the particular cases from the project management tools and contract documents, followed by semi-structured interviews with personnel that were close to or managed the specific projects. The structured questions for the interviews are shown in Table 2, which were iteratively developed throughout the interview process and allowed for the answering of the research questions, as well as leaving open opportunity for responses outside the bounds of the questions. The grounding of theory developed was strengthened by the interpretation of what happened from a first-person perspective and relating it to the project management database information and cross-case analysis.

Table 2. Transition Factor Constructs and Research Questions

<table>
<tr><th>Theoretical Construct</th><th>Research Question</th><th>Interview Questions</th></tr>
<tr><td rowspan="3">People and Commitment</td><td rowspan="3">1) To what degree are people and commitment correlated to transition?</td><td>Was their consistent partnership and commitment?</td></tr>
<tr><td>Was their consistent DIU management?</td></tr>
<tr><td>Was there a Project Champion from the Transition Partner?</td></tr>
<tr><td rowspan="3">Execution</td><td rowspan="3">2) To what degree is acquisition execution correlated to transition?</td><td>Was there seamless contracting and ability to contract in transition? Was this significant to prototype transition?</td></tr>
<tr><td>Did the technology require significant development? Were their technology risks?</td></tr>
<tr><td>Was transition planning and the timing of transition planning significant to prototype transition?</td></tr>
</table>

Resourcing	3) To what degree are resources correlated to transition?	Was availability of resourcing factors such as time and money significant to prototype transition?
Transition Market	4) To what degree is the transition market correlated to transition?	Were there many transition partners that had interest in the prototype?
		Was the prototype easily scalable to different partners or is it unique capability to a single problem set?
Additional Factors	4) Are there other significant project factors that impact transition?	Are there any particular reasons that some prototypes transition and some don't?

3.5.4 Data Analysis

Comparisons between the database information and interview response helped strengthen the grounding of evidence and theory by triangulation and provided a basis for iterative adjustment to data collection needs. Data analysis was also iteratively conducted by both within-case and cross-case pattern searching to ground and validate theories developed. The theories were assessed against both confirmatory and conflicting literature to ensure internal and external validity of the theory.

3.6 Summary

A two step approach was performed to identify factors that are significantly correlated to DIU prototype project transition outcomes. Empirical methods through the use of regression modeling enabled the identification of existing program management data factors that most correlated with transition outcomes. A mix of qualitative and quantitative empirical methods through case studies enabled a deeper dive and theory development about the factors that correlated with transitions.

IV. Analysis and Results

4.1 Chapter Overview

The research was completed according to the research methods discussed in Chapter 3. The statistical analysis of DIU project data provided that the funding and time committed to prototype projects, in the form of obligated funding and period of performance (PoP), had a significant and positive relationship with prototype transitions. The case study analysis offers further investigations into factors of resources, people, execution, and transition market that led to both why prototype projects gained additional resources, and further why they were successfully transitioned. The results of both sets of analysis allowed for the generation of theory on what factors are correlated with technology transition outcomes.

4.2 Data Collection and Preparation

Data was collected from the two program management tools and provided data on 73 completed DIU projects. 15 projects were removed because the awards and execution followed non-standard model and process. The remaining 58 projects were used for the study. Data on the independent variables was compiled and verified through cross referencing between the program management data sources, and the contract documents for the projects.

4.3 Logistic Regression Model Development

Regression model development was completed to identify the factors that were significant in predicting transition success in DIU prototype projects, identify how much of the variability in transition success could be explained by the predictors, and identify best cases for follow on theory development through case study research. The models were developed for three-time phases of information known: 1) information known at time of initial prototype award, 2) information learned through contract execution, 3) information at completion of the contract. This time phased approach offered perspective into what data and factors provide what confidence level of transition at different times in the project. Each model was put through the model development phases in parallel, which included data selection, model formulation, and model output and validation.

4.3.1 Models Factor Selection

To first assess which factors would provide the best fitting model, best subset regression analysis of independent variables in the form of Bayesian Information Coefficients (BIC) was completed (Table 3). The variables of interest varied for each time phase in the models.

Table 3. Bayesian Information Coefficients (BIC) Value of Time Phased Regression Models

	Project at Award	**Project Execution**	**Project Complete**
BIC	1.7	-5.8	-11.0
BIC Identified Significant Factors	Original Obligations	Large Traditional Vendor with Cost Share, Original PoP, PoP changes, Obligation Changes	PoP, Obligated Funds

Lower BIC values show that a model has a better goodness of fit to the actual outcomes. The BIC for each of the best subsets of variables for the prediction of transition shows the BIC gets lower as the project moves from award, to execution, and then completion.

Therefore, the information and factors learned through project execution increases the ability to predict transition likelihood.

Next, a correlation assessment was completed next to ensure multicollinearity did not exist. Multicollinearity problems include variables with correlation above .90. The correlation matrix is shown in Figure 7.

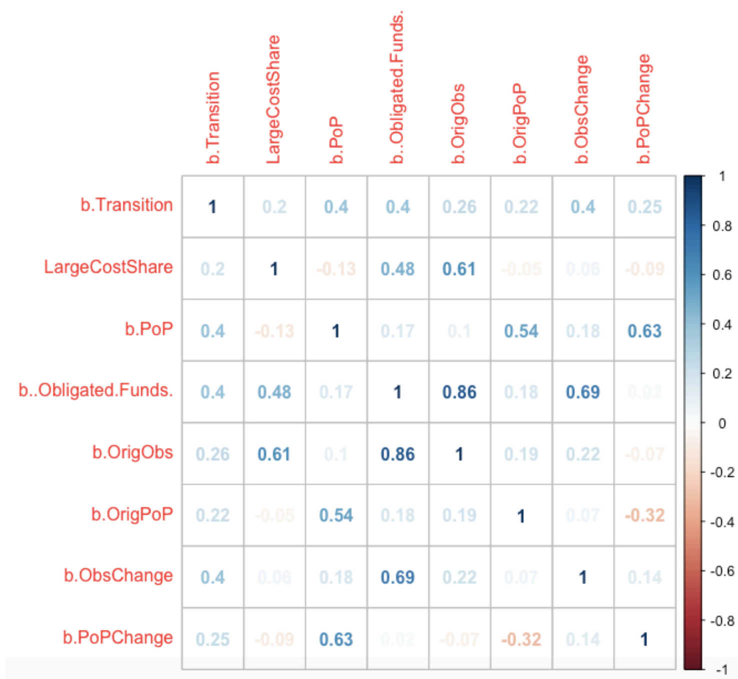

Figure 7. Correlation Matrix of Transition Models Significant Factors

Figure 7 shows no factors with greater than .90 correlation. The factors that are correlated the highest, Original Obligations and total Obligated funds at .86, would not be in the same time phased models and therefore will not impact the models results. This shows that multicollinearity is not a problem with the factors selected for the initial regression models.

4.3.2 Regression Model Development

Logistic regression models were then developed with the variables of interest from both the BIC and best fit analysis. The project execution time frame model had many variables well above the level of significance (p-values greater than .05). Variables were removed one by one from the model in order of highest p-value to lowest. This removal was conducted until only those variables with statistical significance to the dependent variable output remained (Table 4).

Table 4. Transition Logistic Regression Initial and Final Model Factors P-Values

Time Phase of DIU Prototype Project	**Initial Model Factors**	**Initial P-values**	**Reduction to Significant Factors**	**Final P-Values**
Time of Award	Original Obligations	0.036	Original Obligations	0.036
During Execution	Original PoP	0.004	Original PoP	0.049
	Obligation Change	0.02754	Obligation Change	0.019
	PoP Changes	0.036		
	Large Business w/ Cost Share	0.99		
Completion	Total PoP	0.04	Total PoP	0.04
	Total Obligated Funds	0.01	Total Obligated Funds	0.01

Table 4 shows that at time of award the only significant predictor of transition was the original obligations. During execution the significant predictors of transition were the original PoP and obligation changes. At prototype project completion, total PoP and total obligations were the only significant transition predictors.

This modeling shows that significant predictors of transition outcomes in projects are resourcing factors that include time in the form of PoP and money in the form of obligated funds. This outcome also shows that Vendor Type, DoD Partner type, Technology Portfolio, DIU Funding and number of Contract Modifications were not significant predictors of transition. The next step is to identify the variability in transition likelihood in the model described by the significant predictors.

4.3.3 Model Assessment and Validity

To assess the models, a Pseudo R-squared value was found for each model which provides the interpretation of how much variation in the output was described by the factors in the model. To prove that this number was not by happenstance, a p-value for the Pseudo R-squared value in the form of chi-squared analysis was calculated. The values for Pseudo R-squared and the respective p-values are found in Table 5.

Table 5. Pseudo R-squared and P-values for the Transition Regression Models

Time Phase of DIU Prototype Project	**Factors in Model**	**Pseudo R-Squared**	**P-values**
Initial Award Model	Original Obligations	0.126	0.002260
Execution Model	Original PoP and Obligation Changes	0.204	0.000508
Completion Model	Total PoP and Total Obligations	0.280	1.00E-05

All of the Pseudo R-squared have p-values well below 0.05, and therefore are within the 95% confidence interval. This shows that the measurement of variability is unlikely to have been concluded if completed through randomization. The Pseudo R-squared values show that what is known at the initial time of award in obligations, explains about 12.6% of the variability in transition. Information learned in execution, particularly obligation changes, increases the R-squared value to 20.4%. The sum of the obligations and PoP provides an understanding of the variability of transition outcomes at

28%. The changes in projects and post-award funding provides indicators into whether or not a project will transition.

The Pseudo R-squared values provide insight into which factors are likely to have the greatest impact on transition. In this case, it was found that obligation changes made after the initial award provide the greatest variability in DIU prototype project transition outcomes. Figure 8 shows how additional funding is related to prototype project success.

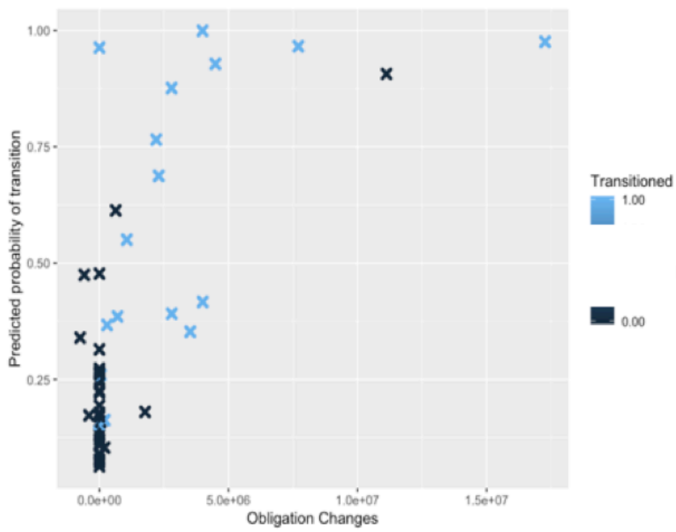

Figure 8. Completed Prototype Transition Likelihood vs. Obligation Changes

Of the 20 prototype projects that received additional funding, 16 transitioned successfully. Of the 38 prototype projects that did not receive additional funding during the prototyping phase, only 3 transitioned by way of follow on programmatic adoption by contract. This shows that receipt of additional funding was correlated with project transition success.

4.3.4 Model Outcomes and Unanswered Questions

The outcomes from the modeling of time phases in the project show that resourcing is correlated with prototype project success. The graph in Figure 9 shows the modeled likelihood of success of each project ranked low to high.

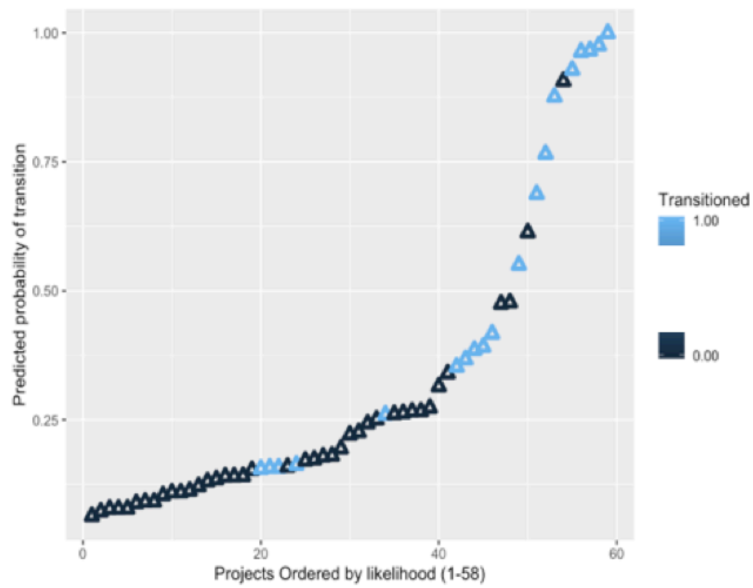

Figure 9. Likelihood Model of Transition at Project Completion

The model shows that though most transitioned projects (light blue triangles), had a high modeled probability of transition, there are still cases with modeled outcomes that prove to be false positives and false negatives. This observation drove further lines of inquiry as to how projects received initial resourcing as well as subsequent gains in resources, why some projects with resources failed, and how projects without resources still succeeded. Therefore, further investigation was required into how projects gained resources and what other factors impact the transition of commercial technology prototypes.

4.4 Building Theory from Case Study

The statistical analysis portion of the study provided that, resource commitments of time and money were leading predictors and influencers in transition success. The addition of further investment of money during prototyping was the strongest influencer in the variability of the modeled transition likelihood. A deeper case study analysis was performed to gain a better understanding of what factors lead to resource availability, and what other factors are correlated with transition likelihood.

4.4.1 Results of Case Study

The regression analysis determined that project characteristics of period of performance, initial funding, and additional funding had a positive and significant relationship with projects transitioning. The modeling enabled selecting cases that met the characteristics of a mix of technology area and hardware and software, and cases that followed the models and theoretical pattern of transition variability being caused by time and money, and model outliers. The selected cases are shown in Table 6.

Table 6. Cases Selected for Case Study

Case	**Technology Portfolio**	**HW or SW**	**Transition Probability (Model Output >.15 = Likely)**	**Transition (Yes/No)**	**Model vs. Reality**
Drone Testing Technology	Autonomy	HW/SW	0.906	No	False Positive
AI Decision Making	Artificial Intelligence	SW	.07	No	True Negative
Big Data Migration and Analytics	Cyber	HW/SW	0.18	No	False Positive
Cyber Risk Analysis	Cyber	SW	.06	No	True Negative
Drone Defense Capture	Autonomy	HW	0.613	No	False Positive
Drone Defense UAV	Autonomy	HW	0.9999	Yes	True Positive
Cyber Intelligence	Cyber	SW	.68	Yes	True Positive

Space Awareness	Space	SW	0.68	Yes	True Positive
Underwater EOD	Autonomy	HW	0.15	Yes	False Negative

The cases of interest were evaluated through semi-structured interviews to identify the factors associated with projects ability to get resourcing, and determine factors that impacted transition results. As hypothesized in the initial constructs from Chapter 3, the interview responses offered factors significant to transition outcomes that could be bucketed into categories of resources, people, execution, and transition market.

4.4.2 Resources as a Transition Likelihood Factor

Resourcing was identified in the regression analysis phase of the study as a critical factor, but investigating how resourcing affected projects from a qualitative perspective helped expand upon this theory. Because of the selection of cases to include outliers from the larger sample size used in the regression model, there were expected discrepancies between the results of the qualitative feedback (Table 7).

Table 7. Resourcing Availability Interview Responses and Additional Funding

Case	Resourcing Availability Interview Response	Additional Funding Post-Award	Transition (Yes/No)
Drone Testing Technology	Yes	Yes	No
AI Decision Making	No	No	No
Big Data Migration and Analytics	No	Yes	No
Cyber Risk Analysis	No	No	No
Drone Defense Capture	No	Yes	No
Drone Defense UAV	Yes	Yes	Yes
Cyber Intelligence	Yes	Yes	Yes
Space Awareness	Yes	Yes	Yes
Underwater EOD	Yes	No	Yes

Of the nine (9) case studies completed, five (5) of the nine (9) projects showed that funding was available when needed for the prototype and production. Three (3) of the projects that did not transition had additional obligations, which was previously shown to be correlated with transition success. These outlier projects indicated that production dollars were not available, though prototyping dollars were.

Feedback that was consistent across the projects was that money was a critical factor in transitioning projects. Quotes from interviewees across the different projects included, "Money's not hard, if they [operational stakeholders] want it bad enough they'll find money", in project selection **"**I separate the wheat from the chaff in projects by how much money is available, and how many years of money", and "Money is a proxy for commitment". From these responses, it was apparent that stakeholder and funding partner commitment is a significant factor that leads to resourcing and therefore transition success.

Interview responses aligned with established factors assessed by the Transition Confidence Levels (TCLs) tool; highlighting an individual's investments, desire and commitment as being a significant factor in gaining resources and project transition. From the literature review, USSOCOM's TCLs tool assesses program factors associated with collaboration and resourcing commitments; as these factors increase, a programs associated TCLs increase (Ballenger & Davis, 2017). Individual and organizational stakeholders, along with their roles and behaviors, is theorized then to be correlated with resourcing and transition success.

4.4.3 People as a Transition Factor

Factors associated with the individuals involved in prototyping projects have an impact on transition. These factors were associated with stability, or turnover, of people in key roles and the placement of those people within stakeholder organizations. From the interviews, the presence of commitment directly correlated to the resourcing available and subsequent transition (Table 8).

Table 8. Resourcing Availability Response and Partner Commitment

Case	Resourcing Availability Interview Response	Committed Partner	Transition
Drone Testing Technology	Yes	Yes	No
AI Decision Making	Somewhat	No	No
Big Data Migration and Analytics	No	No	No
Cyber Risk Analysis	No	No	No
Drone Defense Capture	No	No	No
Drone Defense UAV	Yes	Yes	Yes
Cyber Intelligence	Yes	Yes	Yes
Space Awareness	Yes	Yes	Yes
Underwater EOD	Yes	Yes	Yes

The interviews also provided a breakdown of factors that impacted whether or not commitment existed throughout the project. These factors were the presence of the "right" project champion, project stakeholder consistency, and DIU management consistency. Military turnover due to permanent change of station and other personnel transitions can diminish this consistency. The presence of each of these factors and the related commitment and transition outcomes can be seen in Table 9.

Table 9. Presence of people and commitment related to transition success

Case	Stakeholder Consistency	DIU Management Consistency	Right Project Champion	Committed Partner	Transition
Drone Testing Technology	Yes	Yes	Yes	Yes	No
AI Decision Making	Yes	No	Somewhat	No	No
Big Data Migration and Analytics	No	No	No	No	No
Cyber Risk Analysis	No	No	No	No	No
Drone Defense Capture	No	No	No	No	No
Drone Defense UAV	Yes	Yes	Yes	Yes	Yes
Cyber Intelligence	Yes	No	Yes	Yes	Yes
Space Awareness	Yes	Yes	Yes	Yes	Yes
Underwater EOD	Yes	Yes	Yes	Yes	Yes

4.4.3.1 Turnover as a factor

The interview responses showed that projects that were likely to succeed had committed and consistent prototyping and transition partners. Turnover in terms of DoD partners and organizations had a significant impact on the commitment of the partners to the project success. Specific quotes from projects that did not transition included “Money was readily available for the prototyping phases, but money dried up after DoD partner turnover”, and “We started with the right customer who had the demand and resources, but when management transitioned to another office, there was no longer alignment with the demand or the resourcing partner”. The results showed that there were negative effects of personnel and organizational turnover of DoD partners that was significant to the resourcing of the projects.

DIU management turnover is related to commitment and transition, with seven (7) out of nine (9) cases correlated. In regards to AI Decision Making, DIU management remained with the PM, but portfolio director turnover occurred, leading to new direction, and lack of project sponsorship from a DIU leadership perspective. In other prototyping efforts it wasn't mentioned to be a concern when turnover occurred, though the transition results show otherwise.

In the case where two prototypes were started with the same program office personnel in Drone Defense UAV and Net Capture, it showed a case where turnover led to the loss of sponsorship and a champion. The prototype was highly successful with the UAV effort, which moved quickly through the prototyping and transition process, but the net capture effort did not. According to an informant response, "With the turnover of the champions in the Chief Engineer and Project Manager, the project lost steam. The rest of the office didn't really know what was going on with the prototyping effort, or that these other efforts existed beyond the UAV effort". Having consistency in the individuals in the project, and avoiding turnover shows to be a factor in transitioning prototype projects.

The findings found here are well grounded and alligned with the literature. The correlation of turnover leading to prototype project transition failure is consistent with the findings from Allen and Meyer (1990) and Hall (2008). Turnover correlating with project and transition failure is a theory grounded by the data presented, as well as literature.

4.4.3.2 Project Champion

A project champion was also identified as a critical factor in project transition success. A champion is someone who is the advocate for resourcing and transitioning the prototype from the DoD partner sustainment side. Table 7 shows that seven (7) out of nine (9) projects had correlation between presence of a champion and transition. An example where this was most evident was in the Space Situational Awareness project. The champion was in a mid-grade leadership position, able to allocate resources for prototyping, and owned all roles of transition included in the research review of Champion, Sponsor and Gate Keeper.

Projects that didn't have the appropriate or "right" champion included Cyber Risk Analysis project and AI Decision Making. In Cyber Risk Analysis the champions were too low in the organizational structure. The interviewee offered that "The champions were contractors in support of leadership and were not empowered to allocate resources and did not have the power to champion the project". In the case of AI Decision Making, the tasking came from a general officer, but it was stated in the interview that they were lacking action officer support. The interviewee offered that "Senior Leaders will buy in, but the staffs don't. Need a staff member super committed… Need a champion who will buy-in to the project". These findings are in line with the literature review, specifically having champions that are too high or too low in rank will not lead to project success. Therefore right-sizing the project champion for someone who has the time to support the project, but also is empowered to make resourcing decisions, is found to be a factor in prototyping project outcomes.

4.4.4 Execution as a Factor

Commitment in the forms of project champions and lack of turnover was shown to be significant to transition, but commitment can be gained or lost through the execution of a project. When stakeholder commitment is present, other factors impact a projects transition outcome (Table 9). The Drone Testing Technology project had the commitment and resourcing factors present, but the project did not transition. The interviews of all the cases provide four (4) execution factors, shown in Table 10, that were stated as impacting the transition likelihood of a project. These four (4) factors include goal alignment, degree of technology development (indicated as COTS in Table 10), acquisition processes, and transition planning.

Table 10. Presence of Execution Risk Factors in DIU Prototype Projects

Case	**Goal Alignment**	**COTS Technology**	**Smooth Contracting Workflow**	**Transition Planning**	**Transition (Yes/No)**
Drone Testing Technology	Yes	Somewhat	No	Somewhat	No
AI Decision Making	No	No	No	Somewhat	No
Big Data Migration and Analytics	No	Yes	Yes	Somewhat	No
Cyber Risk Analysis	No	Yes	No	No	No
Drone Defense Capture	No	No	Yes	No	No
Drone Defense UAV	Yes	Somewhat	Yes	Yes	Yes
Cyber Intelligence	Yes	Yes	Yes	Somewhat	Yes
Space Awareness	Yes	Yes	Yes	Somewhat	Yes
Underwater EOD	Yes	Somewhat	Yes	Yes	Yes

4.4.4.1 Goal Alignment

Goal alignment, defined in this project, is when the project plan and end state objectives according to the end users, the resourcing office, testing office and the acquisition office are all consistent. Alignment of stakeholders is typically present when transitions occur (Table 10). Goal alignment issues can occur when there is turnover, as we saw in the previous section, but it can also happen with misalignment between stakeholders.

An example of misalignment is shown in the case of the Cyber Risk Analysis project. The demand for the project came from a resource sponsor, but the execution office and end users were not consulted though they were the organizations who would evaluate and use the capability. This led to the executing office being “actively against and undermining the project, or at best indifferent” according to the interviewee. The cross-case analysis validates that when the prototyping stakeholder offices expectations and goals are aligned there is more likely to have prototype project success and therefore transition.

The literature provides that stakeholder alignment in both commercial and defense sectors is important for transitioning technologies to sustainment. The Navy’s Adoption Readiness Levels offer stakeholders involvement as a factor that is measured as their confidence in technology adoption grows, and also offer that this stakeholder alignment needed to happen early in the projects effort for it to succeed (2017). Ensuring that all stakeholders, including resource sponsoring, user evaluators, and acquisitions are aligned with the projects goals is shown to be a factor in technology transition success.

4.4.4.2 Amount of Technology Development

From the cases studied, no significant difference in transition was observed between the developmental and the non-developmental, or commercial off the shelf (COTS) capabilities, was found. In an assessment of the 30 completed prototype projects that did not transition, only 15% were identified as not transitioning due to technology failure. All of the case studies had technologies that were found successful except Drone Defense Net Capture. In the instance of that case, the technology development did not met established timelines, however the end state of that development did not align with the expectations and goals of key stakeholders.

The literature review offers that technology risks are a common factor evaluated in the challenge of bridging the valley of death, but also offers that other factors have significant play in this area. There still is cost and risk that to prove out a technology that was successful in a relevant environment (Newman, n.d.). The findings that technology failure only accounted for 15% of transition failures and was not found to correlate in the case studies conflict with the risks stated. This may be due to validated commercial technology having more breadth of use case than the TRL 6 metric that typically precedes prototyping in operational environments.

4.4.4.3 Acquisition Process and Planning

Another factor that impacts projects success and transition is the acquisition process and contracting workflow. Three (3) of the five (5) unsuccessful in transitioning projects had provided this as a factor that led to their inability to transition. The reasons for these cases are indicated in Table 11. Projects without these challenges had relatively seamless prototyping awards, and had a transition plan in place.

Table 11. Acquisition and Contracting Challenges in Prototyping Transition

Case	**Acquisition & Contracting Challenge**
Drone Testing Technology	Didn't prototype what was required for production, therefore unable to use 10 U.S.C. 2371b(f) statute.
Cyber Risk Analysis	Six-month contract slip led to lost momentum in project and prototyping partners ended up leaving their positions at time of award.
AI Decision Making	Transition partner prioritized project with funding, but did not have contracting resources to award and manage follow on work.

4.4.4.5 Transition Planning

The presence or lack of transition planning appears to contribute to success and failures to transition respectively. From the interview responses received, they highlighted that early on at DIU, transition was not a focal point as projects were kicked off. That being said, the PMs of projects with distinct transition plans called their projects "easy". This showed in projects like Drone Defense UAV, which had an evaluation and transition plan from the start, and Underwater EOD, which also had their transition plan codified before the prototyping effort began. Transition planning early on in prototyping was found to be significant in prototyping success.

Table 12. Transition Planning and Decision Timing as a Factor of Transition

Transition Planning & Decision	**Prior to Prototype Award**	**Early In Prototyping**	**Late or End of Prototyping**
Cases	Underwater EOD	Cyber Intelligence	AI Decision Making
	Drone Defense UAV	Space Awareness	Big Data
		Drone Testing Technology	Cyber Risk Analysis
			Drone Defense Capture

The result of the interviews indicate that transition planning timing was a factor. This aligns with established best practices, notably in GAO's reporting of technology development and productizing at 3M and Motorola. Additionally, from the Rapid Innovation Fund's transition best practices, Transition Planning and a Technology Transition Agreement should happen either prior to award of their prototyping efforts, or soon after (2016). Timing of transition planning, as found in the interview responses, is in line with literature as being correlated with technology transition success.

4.4.5 Market as a Transition Factor

The final factor of the case study analysis that was the transition market. The transition market addressed in prototypes was bucketed into how many prototyping transition partners were involved and the scalability of the solution; the results are indicated in Table 13. Most prototyped technologies could be easily scaled to multiple partners, but this was not done in most prototypes.

Table 13. Transition Market and its relationship to DIU Prototype Transition

Case	**Multiple Prototyping Transition Partners**	**Scalability of Solution**	**Transition (Yes/No)**
Drone Testing Technology	Somewhat	No	No
AI Decision Making	Somewhat	Yes	No
Big Data Migration and Analytics	No	Yes	No
Cyber Risk Analysis	No	Yes	No
Drone Defense Capture	Somewhat	Yes	No
Drone Defense UAV	Somewhat	Yes	Yes
Cyber Intelligence	Yes	Yes	Yes
Space Awareness	Somewhat	Yes	Yes
Underwater EOD	Somewhat	Yes	Yes

In the cases of Big Data and Cyber Risk projects, the prototyping efforts focused on a single DoD transition partner and therefore were found unsuccessful when that partner decided not to move forward with sustaining the successfully prototyped capability. The Commercial Threat Intel project took the tactic identified in the literature review of being a "marketeer" of the capability, and allowed multiple organizations to prototype the two capabilities that it had on contract. When the primary DoD partner chose one of the capabilities to sustain, because multiple partners tried both capabilities, there was a market for the second prototype that the primary DoD partner did not go to production with.

The responses provided in the cases provided limited cross case evidence in support of understanding the impact of the transition market on these capabilities ability to transition. The responses consisted mostly of additional organizational interest, but no commitments were offered or partner curation occurred. Many of the prototype projects were capable of scaling to many different users and use cases.

4.6 Summary

Regression analysis of program management tool and contracting data sources and case studies based on this data and follow-on interviews provided factors that were significant to prototype transitions. The regression modeling identified best predictors of prototype transition success included PoP and funding at all phases of the prototyping effort. Case studies emphasized that resourcing was significant to transition success and revealed that factors including people, execution and transition market were significant in gaining the resources and time necessary for transition.

V. Conclusions and Recommendations

5.0 Chapter Overview

The research goal was to identify factors in commercial technology prototype projects that correlated with transition to sustained DoD capabilities outcomes. This research delivers, through statistical and case study analysis, empirical evidence of factors that impact technology transition success at DIU. The significance of the research is that the identification of factors impacting prototype transition rates will inform DIU prototype project diligence and management areas of needed attention.

Recommendations are offered for how to improve project diligence with the factors identified in this research, and how to continue the understanding of the transition factors in the future through the completion of after action reports. Future research is suggested to continue to develop theory based on findings of future completed projects to enhance the understanding of prototype transition factors as the technology transfer environment evolves.

5.1 Conclusions of Research

The primary objective for this research was to identify factors that were significant to DIU prototype project transitions. These factors were found to include project resourcing, personnel and organizational commitment, turnover and sponsorship, project execution, and transition market. Factors found to provide little impact on transition likelihood included the amount of DIU funding, which DoD partnering service or agency, vendor size, type of technology, and number of contract modifications.

5.2 Investigative Questions Answered

Q1: What pre-award factors correlate with technology transition likelihood?

The pre-award factor from the qualitative analysis that was identified as being correlated with technology transition was the amount of funding being awarded. From the case study analysis, the identification of personnel commitment, turnover expectations, and stakeholder alignment are also correlated with transition. Additionally, having a transition plan prior to contract award was shown to be correlated with transition success.

Q2: What existing post-award factors correlate with technology transition likelihood?

The regression analysis showed that the presence of additional funding modifications was highly correlated with a prototypes project transitioning. From the case study research, one of the during execution factors that was negatively correlated with prototype transition success that was learned during execution was stakeholder turnover.

Q3: To what degree do the following factors correlate with transition?

- *Resourcing*

Resourcing in prototype projects was found to be a significant predictor of transition from the regression model development and case studies. One of the most significant factors correlated with transition success is access to follow on resources beyond the initial award funding. Resourcing was also identified as resulting from the existence of other more qualitative factors like commitment and consistency of stakeholders.

- *Technology Vendor Type (Large or Small Business, traditional or non-traditional DoD Vendor, etc.), Technology (Space, Cyber, Artificial Intelligence, Autonomy, Human Systems), & DoD Partner (i.e. which Military Service Branches and Agencies)*

The regression modeling provided that these factors were not significant in the prediction of transition. Additionally, the type of technology, type of vendor, or specific partner was not found to be a significant factor from the interview responses in the case studies.

- *People Commitment*

The case studies showed that people are a significant factor in transition. People factors that occurred in prototypes that were found to impact transition were personnel and organizational turnover, as well as having the right champion to advocate and sponsor the prototyping effort and transition.

- *Project Execution*

Project execution significant in the transition likelihood. The subfactors of execution that were found to be significant include acquisition and contracting execution, goal alignment among stakeholders, and transition planning and decision timing. Technology challenges were not present in many of the case studies and the program management data, potentially due to the prototyping of technologies already validated by the commercial market.

- *Transition Market*

The results provided limited cross-case evidence for the transition market as a factor, because only a few interviews were able to identify how the existence of multiple transition partners led to transition success. The literature review, and a selection of cases in the case study, offered that expanding the transition plans to multiple partners led to transition success. Though many of the technologies were identified as being scalable to multiple DoD partners, it was found in multiple cases that courting one transition partner resulted in a single point of failure for transition plans.

5.3 Significance of Research

This research identified factors that correlate with transition outcomes of DIU prototype projects. Including these factors in DIU project diligence can provide a better understanding of what risks a project has with the presence, or lack, of the identified factors. The implications of the research are better DIU prototype project risk assessments which could improve project selection, and selected project transition success rates.

5.4 Recommendations for Action

The recommendations from the researches findings are for DIU to perform After Action Reports (AAR) at the completion of projects to identify factors that lead to success and failures of projects, and then implement diligence changes to perform risk assessment of those factors. Throughout the data gathering efforts and interviews, it became apparent that this research would be the only documented AAR for the cases investigated. AAR's would greatly improve the ability to share knowledge on why projects succeeded and failed to transition, as well as enable trend analysis for what factors are impacting outcomes.

From the results of this study, a project diligence update would include a more thorough analysis of resources, stakeholder's commitment and duty timelines, execution planning, and the overall transition market. To improve understanding of the risk factors associated with prototype transitions during project diligence, Program Managers looking to prototype and transition commercial technologies should identify answers to the following questions:

- Resourcing
  - Did the partner allocate resources required for the prototyping effort?
  - Does the DoD partner have access to additional resources if needed?
  - Does the DoD partner have funding prepared for transition?
    - Is funding in a Program Objective Memorandum request, or is funding available in the current budget?
- People
  - Are all the right stakeholders involved?
  - Is there a project champion? What is the champion's rank/role? Can they effectively advocate for the project, attain resourcing, and make decisions?
  - Do stakeholders have a planned turnover cycle that will occur in the project/transition? Are they seeking other job opportunities?
  - How committed is the prototype partner to this project?
  - Is the DIU PM able to remain for the life of the prototype and transition?
- Execution
  - What is the problem? Is it clear and concise? Are the organizational stakeholders responsible for resourcing, requiring and evaluation aligned on the problem and the goals of the project?
  - What are the planned timelines for acquisition activities? Has this been coordinated with all stakeholders?
  - How much development is required for the prototype? Does this align with transition planning?

  - How will this be evaluated? Who is going to test and evaluate this? Do they have what they need?
  - What is the acquisition plan for transition? Is there a contracting office that has agreed to take this on if successful?
- Transition Market
  - Who (DoD and commercial) will use this in production? How are their interests included in the down-select?
  - Have additional transition partners been engaged for their interest in the prototyping effort?
  - Who else might want to be involved in the prototyping project who could possibly transition the capability?

Answering these questions, or understanding which questions do not have answers provides a more granular assessment of transition risk factors than DIU's current project diligence, and therefore could improve project decision making and transition outcomes.

5.5 Recommendations for Future Research

This research was conducted from a regression standpoint with 58 samples, and from a case study standpoint with nine (9) samples. Future research should be conducted to continue to gain understanding of factors that impact transition as the data becomes available. "The experiments we do today, if successful, will need replication and cross validation at other times under other conditions before they can become an established part of science, before they can be theoretically interpreted with confidence" (Campbell

& Stanley, 1963). This research provides theory developed from a limited sample size. To improve the confidence in the theory, the research should be updated as more projects are completed.

Also, the transition market was identified in the literature reviews as a significant factor and was shown in one (1) of the cases as leading to success, and two (2) of the cases showed how a single point of failure transition partner led to not transitioning the prototyped capability. Though this research did not find enough evidence to end with grounded theory in the transition market factor, further research should be done to assess how this factor may, or may not, correlate to technology transition success.

5.6 Summary

This research has found that DIU has a transition success rate of 32.7%, with only 15.5% of the transitions failing due to not meeting technical requirements. Through statistical analysis and further case studies it was determined that project resourcing is the most critical factor in whether or not a project transitions, but this resourcing has many further determining factors to include stakeholder commitment, stakeholder turnover, execution of the prototyping acquisition, and the addressing of the transition market.

Recommendations were made to improve project diligence by including a series of questions that would ensure these transition risk factors are addressed. A follow-on recommendation was for DIU to include AARs as a mandatory document to ensure that data is available for further research and pattern analysis to determine prototype transition factors as the technology transfer environment evolves. Recommendations for further research include further research into transition market as a factor in regards to transition outcomes, as well as continued theory assessment, development and validation of factors that correlate with transition as more projects complete and the transition environment evolves.

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14. ABSTRACT A key metric of success for Department of Defense (DoD) Research and Development organizations is the ability to "transition" technologies and prototypes. Office of the Undersecretary of Defense for Research and Engineering's prototyping guide shows successful transition pathways come in the forms of transition to operational use, rapid fielding, existing program adoption, or a new acquisition program (2018). There are many factors that occur throughout a prototype project's lifecycle that impact the likelihood of transition. These factors include both qualitative and quantitative factors. Limited research has been performed, past the best practice considerations, of what factors impact transition of prototyping efforts. This research evaluates commercial technology prototyping projects to identify the project characteristics and factors that correlate with transition success. The research setting is DoD's commercial product prototyping organization, the Defense Innovation Unit. The findings show that beyond technology success, the resources of time and money, stakeholder commitment and consistency, project execution and transition market factors correlate with transition success.			
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