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Cost Effectiveness Analysis of the use of Colorless Appropriations in Navy and DoD Software Development Pilot Programs

December 2022

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ABSTRACT

Modernization of the Defense Acquisition Management and federal budget appropriation systems is necessary to ensure technological warfighting advantage, particularly in support of the Department of Defense's software and cyber transition to a Development Operations (DEVOPS)/Development Security Operations (DEVSECOPS) environment. In appropriations, one modernization effort has been reform initiatives utilizing "colorless" appropriations for software-intensive defense acquisition programs. This thesis examines a sample of these pilot efforts through a combination of cost-effectiveness analysis and qualitative reflection to evaluate for efficiencies gained. While quantitative assessment identifies improved effectiveness at lower costs, sparsity of available data and program-specific external variables limit the statistical significance. However, qualitative insights in combination with commercial industry best practices may enhance the efficacy of this and other future reform efforts. These recommendations include additional selection criteria for pilot programs, additional metrics for quantitative and qualitative data collection, and further policy updates to enable a more effective transition from traditional appropriations. These conclusions derive from Defense Acquisition Management; federal budgeting and financial management; defense Planning, Programming, Budgeting, and Execution processes; DEVOPS/DEVSECOPS practices; and Agile and Lean principles.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAF	Adaptive Acquisition Framework
ATO	Authority to Operate
BA	Budget Activity
BA-8	Budget Activity 8
BCA	Budget Control Act
BNVA	Business Non–Value Added
CBA	Capabilities Based Assessment
CEA	Cost-Effectiveness Analysis
CR	Continuing Resolution
CVA	Customer Value-Add
DAS	Defense Acquisition System
DEVOPS	Development Operations
DevSecOps	Development, Security, and Operations
DIB	Defense Innovation Board
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DMAIC	Define, Measure, Analyze, Improve, Control
FFRDC	Federally Financed Research and Development Center
FRCB	Fleet Readiness Certification Board
FMB	Financial Management Board
FMR	Financial Management Regulation
FY	Fiscal Year
FYDP	Future Year Defense Program
JCIDS	Joint Capabilities Integration and Development System
JROC	Joint Requirements Oversight Committee
JES	Joint Explanatory Statement

LOE	Line of Effort
MFP	Major Force Program
MOE	Measure of Effectiveness
MPG	Miles-Per-Gallon
MTC2	Maritime Tactical Command and Control
MVCR	Minimum Viable Capability Release
MVP	Minimum Viable Product
NCSA	Naval Cybersecurity Awareness
NDAA	National Defense Authorization Act
NIWC	Naval Information Warfare Center
NVA	Non–Value Added
O&M	Operations and Maintenance
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
PE	Program Element
PM	Program Manager
PPBE	Planning, Programming, Budgeting, and Execution
RDT&E	Research, Development, Test, and Evaluation
RMI	Risk Management Information
SEI	Software Engineering Institute
SLOC	Source Lines of Code
SWAP	Software Acquisition and Practices
SWP	Software Acquisitions Pathway
VSM	Value-Stream Management

I. INTRODUCTION

Department of Defense (DoD) acquisitions and Congress have aligned goals for software development in a transforming era of technology. Both parties desire a more adaptive and agile process that enables faster transitions between the warfighter (end user) requirements, the development process, and delivery back to the warfighter. In software acquisition terms, this is called delivery cadence. A recent pilot reform effort in this operating space has been to change the way that DoD program offices for software-intensive projects budget and obligate appropriated money. Rather than the traditional method of using separate funding lines ("colors of money") for phases of development (e.g., research and development, procurement, and operations), these pilots are given a single funding appropriation ("colorless money") under Budget Activity 8 (BA-8) for all phases. On the surface, the concept seems quite logical; software should be a continuously evolving process that blurs the lines—or, at the very least, demands rapid transitions—between the various phases of development. If the process is rapid and continuous, then distinguishing between phases of development is not only difficult and ambiguous, but it can be an impediment to these transitions and therefore an obstacle to delivery cadence.

In this paper, the researchers seek to analyze the effectiveness of this pilot reform through a cost-effectiveness analysis on both quantitative and qualitative aspects of these programs. Specifically, the researchers evaluate the program's historical performance under traditional colors of money appropriations, performance with colorless money, and the performance of a comparable control program. Evaluation metrics include delivery cadence, cost, and man-hours (specifically for budgeting). The researchers seek to identify what benefits to the DoD are gained by this colorless funding approach to software acquisitions and to provide recommendations for further future implementation of colorless appropriations.

The researchers utilize data gained from the Maritime Tactical Command and Control (MTC2) program, which is one of the eight programs chosen to participate in the pilot. A cost-effectiveness analysis (CEA) is conducted for comparison of historical data of man-hours and delivery cadence to previous fiscal years (FYs) in the MTC2 program where traditional funding was utilized and to another program using the traditional funding model. This program, Naval Cybersecurity Awareness (NCSA), was not chosen for the pilot program, but provides similar data to the MTC2 program for ease of comparison between a program using colorless funding and one using traditional funding. The analysis displays how colorless money results in slightly greater effectiveness in the areas of man-hours and cadence. However, further data and measures of effectiveness may provide more clarity to decision-makers in the future, and the researchers provide recommendations to address this gap.

In addition to the data on man-hours and delivery cadence, MTC2 cost data are used to compare the cost differences from before and after implementation of BA-8 funding. This analysis shows clear savings after implementation.

Qualitative aspects of the implementation of their programs are also part of the reports provided by MTC2 and NCSA. These qualitative aspects include answers to questionnaires given to them as part of the pilot program and provide insight into some of the difficulties faced during implementation and their recommendations. The researchers analyze these factors and provide recommendations for future implementation to address them. Additionally, the researchers provide recommendations based on the CEA and qualitative data to determine how colorless money could benefit larger acquisition programs such as those for submarine combat systems.

The next chapter provides a background of federal budgeting, software acquisitions, and the BA-8 pilot program. Chapter III describes the methodology for the CEA, cost analysis, and qualitative analysis. Following that, Chapter IV presents a CEA of traditional and colorless money appropriations. The researchers address the research questions through an analysis of costs and qualitative data and provide recommendations based on this analysis. Finally, the last chapter summarizes the researchers' findings and conclusions and provides recommendations for implementation in future research.

II. BACKGROUND

To understand the nature of the problem, the reader must first understand the current state of defense acquisition and federal budgeting structures, the Defense Acquisition System (DAS), and the pathways of the Adaptive Acquisition Framework (AAF). This section describes the nature of these interconnected functions, identifies conflicts between the systems, and introduces the FY2021 Software and Digital Technology Pilot Program, specifically looking at the Navy's MTC2 program.

The first step in understanding how these programs function is understanding the Big "A" acquisitions process within which they operate. Big "A" acquisitions, as described by Robert Mortlock in his 2021 article, are founded in what is commonly referred to as the triple constraints: cost, schedule, and performance. As displayed in the same article, these three foundational ideas for program acquisitions represent three DoD decision support templates that work together to deliver capability to the warfighter. Performance is determined by the Joint Capability Integration and Development System (JCIDS); program cost is governed by the Planning, Programming, Budgeting, and Execution (PPBE) process; and schedule is set by the milestones created by the AAF, which all work together to form the Big "A" acquisitions process (Mortlock, 2021). Understanding these three pillars is essential to understanding acquisitions as a whole and the balance that a program manager (PM) must maintain throughout the execution of their project.

A. THE JOINT CAPABILITIES INTEGRATION DEVELOPMENT PROCESS

The JCIDS process replaced the Requirements Generation System in 2003 to identify requirements gaps and close them with a focus on joint interoperability. JCIDS is a decision-making tool that begins with performing a Capabilities Based Assessment (CBA). The CBA results inform the rest of the acquisitions process (Defense Acquisition University [DAU], n.d.-a). The Joint Requirements Oversight Council (JROC) oversees the application of this process and advises the Chairman of the Joint Chiefs of Staff in creating capability to meet the needs of the National Defense Strategy (DAU, n.d.-b).

However, for this research, the provisions in the FY2020 National Defense Authorization Act (NDAA, 2019) exempt software programs operating under Budget Activity 8 (BA-8) funding authorization from the JCIDS process until the JROC can create a new software requirements development approach.

B. FEDERAL BUDGET AND APPROPRIATIONS FRAMEWORK

To better understand the process behind BA-8 funding, it is important to understand the current structure of the DoD budget process. Overall, the budget process is governed by the Office of Management and Budget (OMB) Circular A-11, Volumes 2A and 2B of the DoD Financial Management Regulation (FMR), and service-specific guidance. The FMR lists the guidance pertaining to the different budget exhibits that may be required for a given program. The types of budget exhibits that are of concern in the case of software acquisition and the associated BA-8 funding are the budget exhibits for operations and maintenance (O&M); research, development, test, and evaluation (RDT&E); and procurement. As described in Philip Candreva's 2017 book, *National Defense Budgeting and Financial Management*, budget exhibits supporting requests for O&M appropriations are called "O-Forms," while RDT&E appropriations are known as "R-Forms," and procurement appropriations are named "P-Forms." The process is such that each budget is submitted three times in the budget formulation phase: first to the Service budget office for review, then to the Office of the Secretary of Defense (OSD) and ending with the final submission to the President's budget (Candreva, 2017).

In addition to the burden of generating multiple budget exhibits and supporting documentation, there are differences in funding level. As described in Candreva's 2017 book regarding the nature of program elements (PEs), major force programs (MFPs), and funding levels, for a program to be funded, it must be assigned a PE. A PE is generally defined by its categorical appropriation, its respective service, and the major force program (MFP) that the program most directly enhances or supports. MFPs are broad categories that aggregate multiple PEs containing the resources necessary to achieve an objective or fulfill the requirements of a strategic plan. The confluence of these categories is visually represented in Figure 1. Having been assigned a PE, a program then must follow legal restrictions placed on appropriations. One of the more significant constraints is that of full versus incremental funding. In general, procurement appropriations must be fully funded; that is, the full procurement cost of the item or system being procured must be budgeted in the year which the order is placed. Alternatively, research and development or operations and maintenance are funded on an incremental basis; that is, one year's worth of costs of the ongoing activity is budgeted for that year (Candreva, 2017). The particulars and nuances of these requirements become quite cumbersome, and especially so when considering the nature of a continuously developing and operating software-based program.

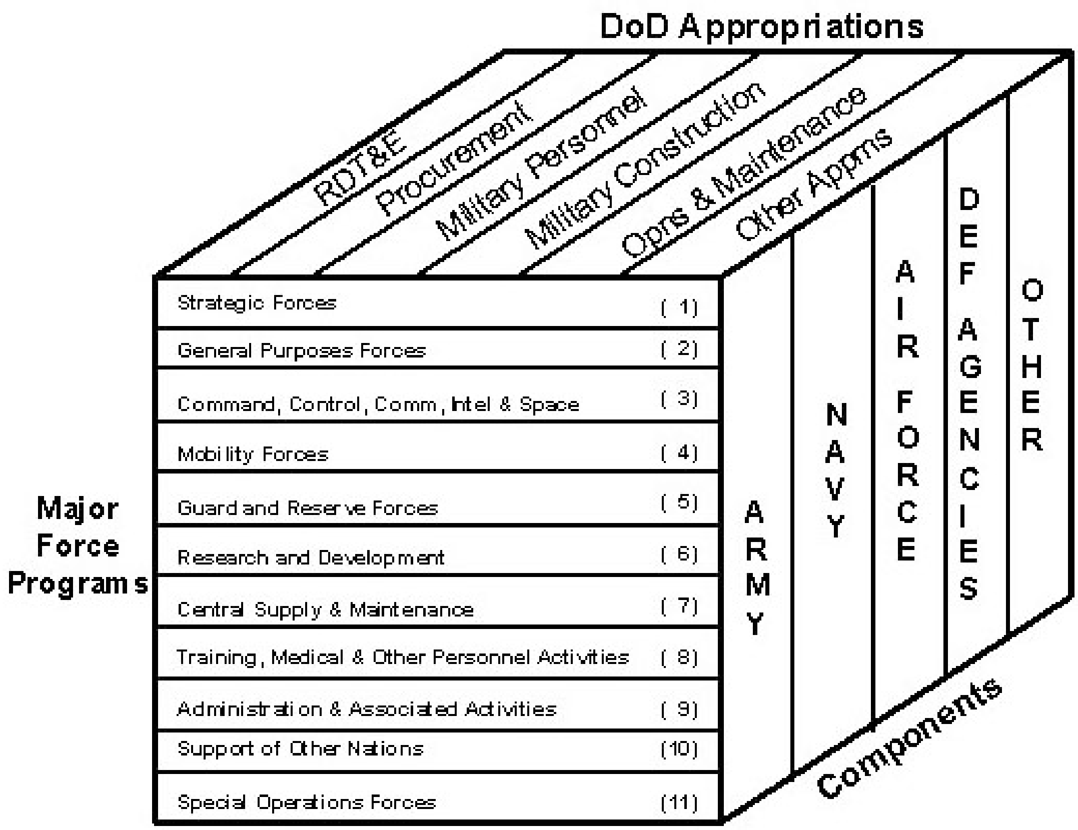

Figure 1. Future Years Defense Program (FYDP) Structure.
Source: DAU (n.d.-c).

Moving into the budget execution phase, each program then must comply with all pertinent laws and regulations in the use of its allocated funds. This means ensuring that all appropriations for legal expenditures of funds meet the purpose of the obligation, occur within the necessary time limits, and are within the authorized amounts (Candreva, 2017). Therefore, any RDT&E (2-year appropriation) expenses must meet the requirements for that budget appropriation, and the same applies for O&M (1-year appropriation) funds. Procurement (3-year appropriation), has the same restrictions, but again, is constrained by the full funding requirement previously discussed. While a procurement appropriation has a 3-year life, full funding must be adhered, and cannot cross FYDP years to meet that requirement. If there are any increases or decreases in budget authorities to a different purpose, those changes require a reprogramming request. This displays the rigidity in the use of funds. BA-8 funding, however, seeks to increase the flexibility in the use of these funds by creating a single budget line item allowing for the allocation of RDT&E, procurement, sustainment, and O&M funds. Not only does BA-8 funding simplify the process for developing the software acquisitions budget and obligation of these funds in software development, but it also eliminates any potential need for reprogramming.

C. ADAPTIVE ACQUISITION FRAMEWORK

The next concept useful for understanding the potential benefits of BA-8 funding in software acquisitions is the AAF and the associated Software Acquisition Pathway. DoD Directive (DoDD) 5000.01 and DoD Instruction (DoDI) 5000.02 describe the DAS and the AAF (Office of the Under Secretary of Defense for Acquisition and Sustainment [OUSD(A&S)], 2022a, 2022b). The development of the AAF created several types of acquisition pathways to meet the various requirements and speed of acquisition required in today's military. This includes urgent capabilities, major capabilities, software, defense business systems, and services, each of which is displayed in Figure 2. Each pathway is tailored to better suit the type of capability being delivered.

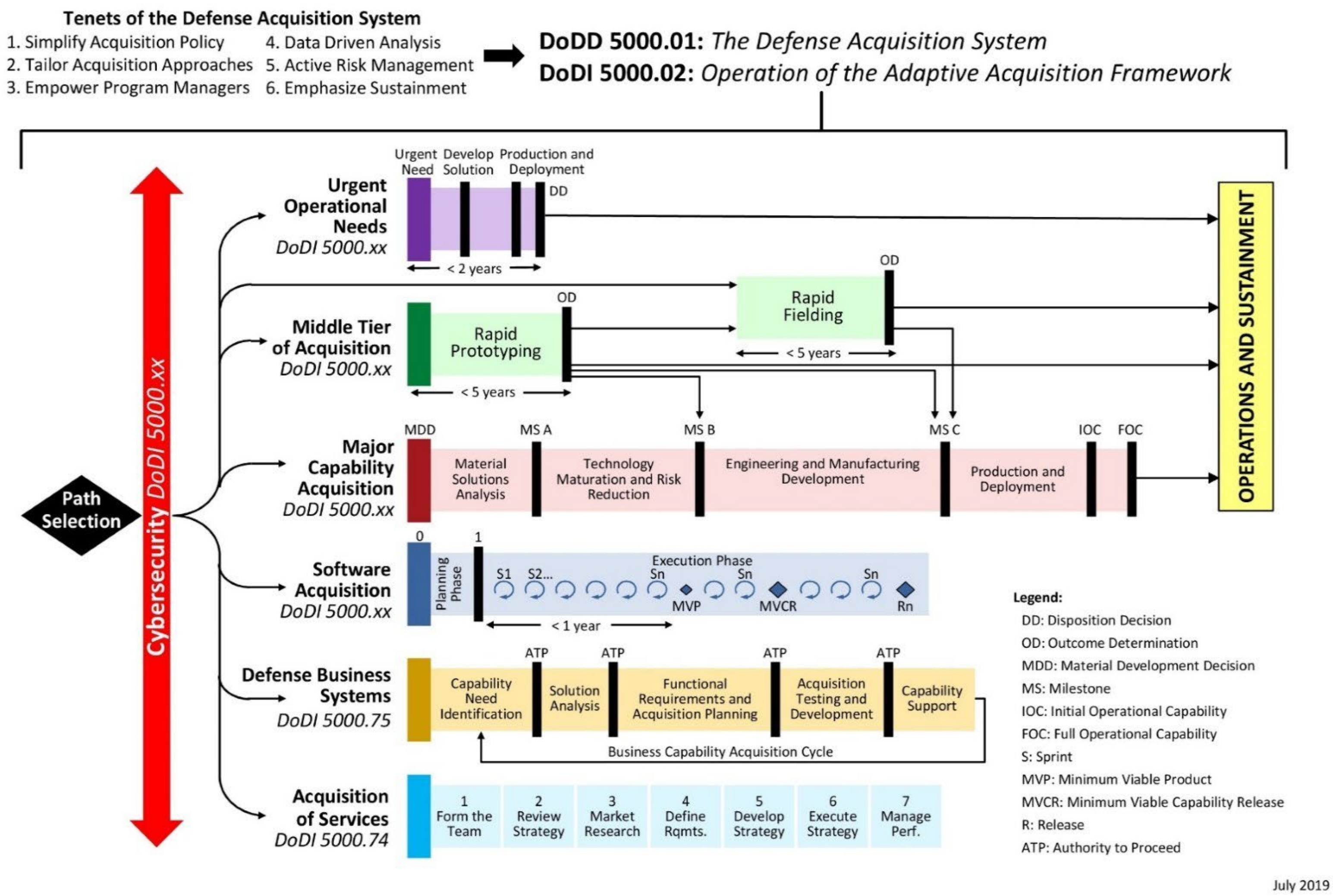

Figure 2. Adaptive Acquisition Framework Pathways. Source: OUSD(A&S), (2022a).

Within the AAF is the Software Acquisition Pathway (SWP), which is designed for software-intensive systems (see Figures 3 and 4). In the case of software acquisitions, the DoD is seeking to match the rapid, iterative approach inherent in this type of acquisition. The objective of this pathway is to "facilitate rapid and iterative delivery of software capability to the user" (OUSD[A&S], 2022b, p. 14). Furthermore, it is described as integrating agile software development, DevSecOps (Development, Security, and Operations), and lean practices (OUSD[A&S], 2022b). Programs using this pathway demonstrate the viability of the operational use of their software no later than 1 year after the date that the funds are obligated. New capabilities are then delivered to operations annually to meet requirements. This aligns with the use of modern software development techniques to iteratively deliver software in collaboration with the operator's input along the way. This modern approach can also be described as DevSecOps (OUSD[A&S], 2020). The pathway is further split into the applications path and the embedded software path. The applications path is meant for software running on commercial hardware, while the embedded software path is intended for the "insertion of upgrades and improvements to software embedded in weapon systems and other military-unique hardware systems" (OUSD[A&S], 2020, p. 8).

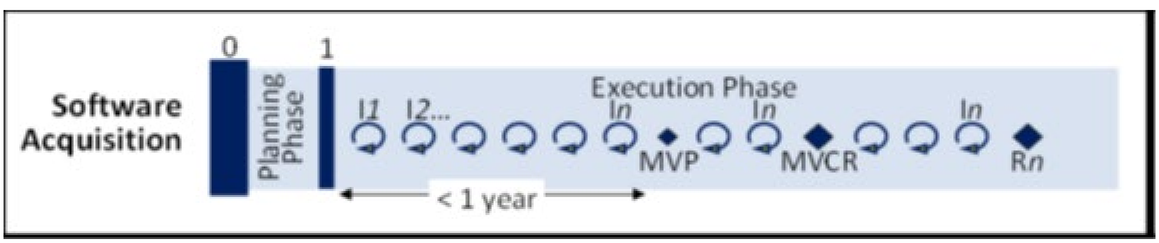

Figure 3. Software Acquisition Pathway. Source: OUSD(A&S), (2022a).

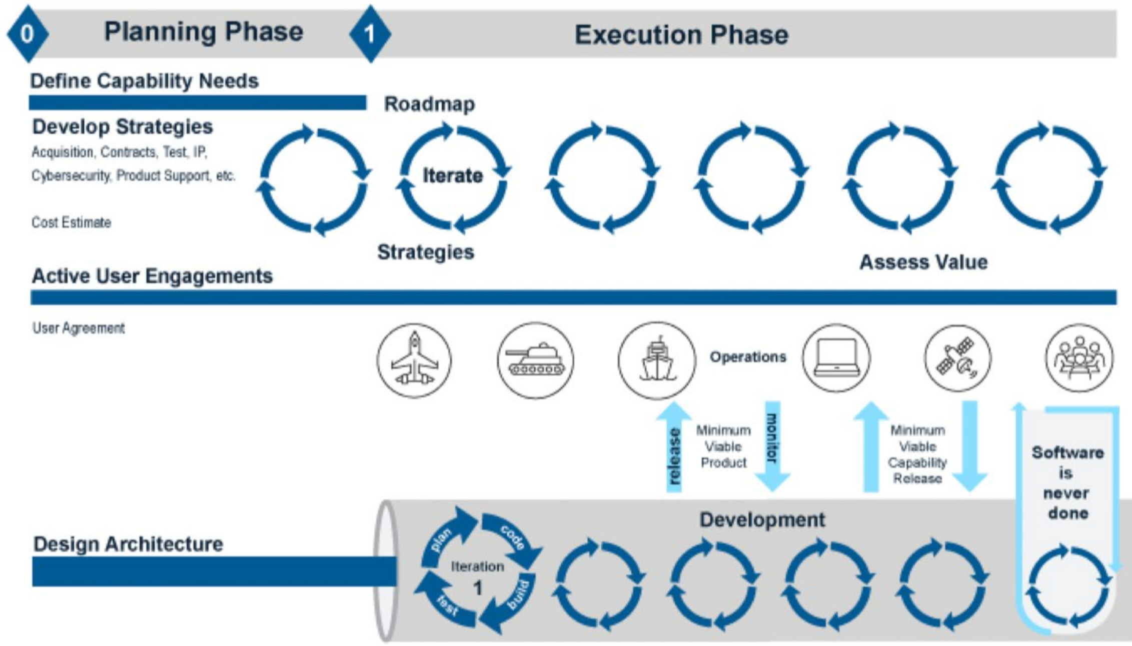

Figure 4. Software Pathway Phase View. Source: OUSD(A&S), (2020).

DoDI 5000.87, Operation of the Software Acquisition Pathway, describes the pathway in detail. DoDI 5000.87 directs the PM to "develop a product support strategy … that treats software development as a continuous evolution of capability across the lifetime of the system, rather than assume discrete 'acquisition' and 'sustainment' phases" (OUSD[A&S], 2020, p. 15). In the Execution phase, SWP programs are to maximize the use of "continuous integration and continuous delivery of software capabilities, and frequent user feedback and engagement" (OUSD[A&S], 2020, p. 16). Furthermore, these programs should "develop and maintain program backlogs that identify user needs in prioritized lists. The backlogs allow for dynamic reallocation of current and planned software releases. … Regular stakeholder feedback and inputs will shape the product roadmap and program backlogs" (OUSD[A&S], 2020, p. 16). Regarding PM and sponsor responsibility for defining requirements, they should "use an iterative, human-centered design process to define the minimum viable product (MVP) recognizing that an MVP's definition may evolve as user needs become better understood. Insights from MVPs help shape scope, requirements, and design" (OUSD[A&S], 2020, p. 16). The practices directed in DoDI 5000.87 for SWP describe a process that is defined by continuous interaction between the PM, development team, and end user. With each new capability released to meet an identified requirement, human-centered design demands new feedback to drive evolving capability needs and requirements. DoDI 5000.87 directs SWPs to deliver a minimum viable capability release (MVCR) "to an operational environment within 1 year after the date on which funds are first obligated to acquire or develop new software capability including appropriate operational test" (OUSD[A&S], 2020, p. 16). Furthermore, "Subsequent capability releases will be delivered at least annually" (OUSD[A&S], 2020, p. 16).

D. CONFLICTS BETWEEN FEDERAL BUDGET AND APPROPRIATIONS AND THE ADAPTIVE ACQUISITIONS FRAMEWORK

Currently, program managers use the traditional budgeting and appropriations framework to structure their acquisition of a platform, capability, or weapon. This approach requires PMs to execute the current FY's budget, defend the next FY's budget in front of Congress, and program the President's budget 2 years out. Additionally, PMs must plan for the use of RDT&E, O&M, and procurement dollars depending on the acquisition program phase. These three categories have rigid timelines that restrict their use, and program offices justify the need to move money from one category to another based on the acquisition program baseline. For example, when a program of record has planned Milestone C review to move from engineering and manufacturing development phase to production and sustainment phase, the planned funding transitions from RDTE (2-year money) to procurement (3-year money) and O&M (1-year money).

Despite the hurdles, the traditional approach to funding DoD programs is a proven process for acquiring tangible items such as a new aircraft, ship, or vehicle while also maintaining oversight of the DoD. These tangible item acquisitions have well-defined requirements, and one can accurately predict how long that item will last. This allows the DoD to annually program and plan resources for acquisition programs to meet the future needs of the warfighter.

While tangible item needs are relatively predictable and easier for resource planning, software needs arise quickly and must be answered quickly. Much like the themes echoed in the Defense Innovation Board's (DIB) 2019 report, the time from identifying a need to when it must be met can be a matter of weeks and is one of the most important metrics for managing software. This short timeline does not align well with an annual budget that requires program offices to plan out each year's RDT&E, O&M, and procurement funds. As a result, warfighters may lose capability when they need it most, and taxpayer dollars are not used efficiently. Additionally, in a DevSecOps environment, software developers and program managers have difficulty in determining when each budget activity ends and when another begins (Defense Innovation Board [DIB], 2019). Such is the nature of continuously developing and deploying software at the same time.

Under the traditional budgeting and appropriations framework, a program office might be able to identify a software need and develop a solution, but if they did not foresee this need 2 years ago while preparing the current FY's budget, they could end up unable to deploy this crucial software to the warfighters who asked for it in a timely manner.

An additional issue for software acquisitions within the traditional budget framework is continuing resolutions (CRs). CRs are not convenient for any program, but they pose a unique challenge for software acquisitions. Under a CR, a program may continue to execute under the previous FY's authorization and may not start any new work (Candreva, 2017). How is new work defined for software? Does a new version constitute new work? Or does a quick fix identified by an operator qualify?

SWP and DevSecOps are inherently fast and involve approaches that evolve with a much shorter cycle time than the existing federal budget and appropriations funding timelines. The DIB (2019) recommended that "a continuous deployment approach is needed for delivering on the evolving needs culled from user involvement combining RDT&E, O&M, procurement, and sustainment actions within weeks of each other, not years" (p. 124). As stated by Candreva (2017), the budgeting and appropriations system demands matching a capability need to a requirement, a requirement to a program, and a program to an associated cost estimate for a specific line item in a budget request. This federal budget structure creates a system wherein the DoD must define a program end state to receive a budget appropriation. In defining a well-managed DevSecOps program, the DIB suggested that "the primary focus for DevSecOps programs is about regular and repeatable, sustainable delivery of innovative results on a time-box pattern, not on specifications and requirements without bounding time" (DIB, 2019, p. 119). The way things are currently, the “fixed-requirements spiral-development spending model has created program budgets that approach infinity” (DIB, 2019, p. 119). In other words, attempting to lock in requirements, when software requirements will undoubtedly grow, results in an exponential growth of program costs. In program management terms of the triple constraint model, traditional versus agile approaches to balancing cost, performance, and schedule are visually represented in Figure 5. This sentiment was summarized in the SWAP study: “Software is never done and not all software is the same, but generally the work should look like a steady and sustainable continuum of useful capability delivery” (DIB, 2019, p. 120).

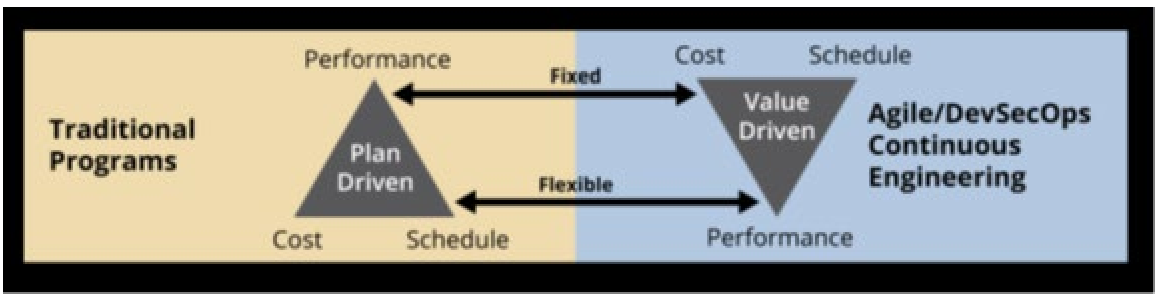

Figure 5. Traditional versus Agile Triple Constraint Model. Source: DIB (2019).

E. SELF-AWARENESS AND REFORM ACTIONS

Section 942 of the 2017 NDAA (2016) established the Commission on the National Defense Strategy for the United States to examine the 2018 National Defense Strategy. The commission, among other conclusions, specifically noted, “Due to the effects of the Budget Control Act (BCA) of 2011 and years of failing to enact timely appropriations—America has significantly weakened its own defense” (National Defense Strategy Commission, 2018, p. vi). Furthermore, the commission recommended that Congress consider increased flexibility in DoD budget authority by extending O&M funds across FYs and producing multiyear budget agreements for defense (National Defense Strategy Commission, 2018).

Section 872 of the 2018 NDAA (2017) directed the DIB via the secretary of defense to conduct a study on streamlining software development and acquisition regulations. The tasking from the NDAA for FY2018 defined the scope of this study as follows:

- Review the acquisition regulations applicable to, and organizational structures within, the Department of Defense with a view toward streamlining and improving the efficiency and effectiveness of software acquisition in order to maintain defense technology advantage.
- Review ongoing software development and acquisition programs, including a cross section of programs that offer a variety of application types, functional communities, and scale, in order to identify case studies of best and worst practices currently in use within the Department of Defense.
- Produce specific and detailed recommendations for any legislation, including amendment or repeal of regulations, as well as non-legislative approaches, that the members of the Board conducting the study determine necessary to:
- Streamline development and procurement of software.
- Adopt or adapt best practices from private sector applicable to Government use.
- Promote rapid adoption of new technology.
- Improve talent management of the software acquisition workforce, including providing incentives for the recruitment and retention of such workforce within the Department of Defense.
- Ensure continuing financial and ethical integrity in procurement.
- Protect the best interests of the Department of Defense. I
- Produce such additional recommendations for legislation as such members consider appropriate. (NDAA, 2017, pp. 215–216)

Furthermore, Sections 873 and 874 of the 2018 NDAA directed the DoD to identify software development programs that could adopt agile best practices and "simplify software development requirements and methods for both software-intensive warfighting systems and defense business systems" (NDAA, 2017, p. 216).

In response, the DIB then conducted a Software Acquisition and Practices (SWAP) study, with results published in May 2019. The SWAP study identified three fundamental themes and four main lines of effort (LOEs) to reform software acquisitions within the DoD. The fundamental themes identified in the SWAP study were as follows:

- Speed and cycle time are the most important metrics for software.
- Software is made by people for people, so digital talent matters.
- Software is different than hardware (and not all software is the same). (DIB, 2019, pp. vii–viii)

The SWAP study then identified these four main LOEs to address the above themes as follows:

- Congress and DoD should refactor statutes, regulations, and processes for software.
- The Office of the Secretary of Defense (OSD) and the Services should create and maintain cross-program/cross-Service digital infrastructure,
- The Services and OSD will need to create new paths for digital talent (especially internal talent).
- DoD and industry must change the practice of how software is procured and developed. (DIB, 2019, pp. x–xi)

Figure 6 provides a visual representation of the interaction between DIB SWAP study themes and LOEs. Within LOE A, the DIB recommended that Congress and the OSD "create a new appropriation category for software capability delivery that allows (relevant types of) software to be funded as a single budget item, with no separation between RDT&E, productions, and sustainment" (DIB, 2019, p. xv).

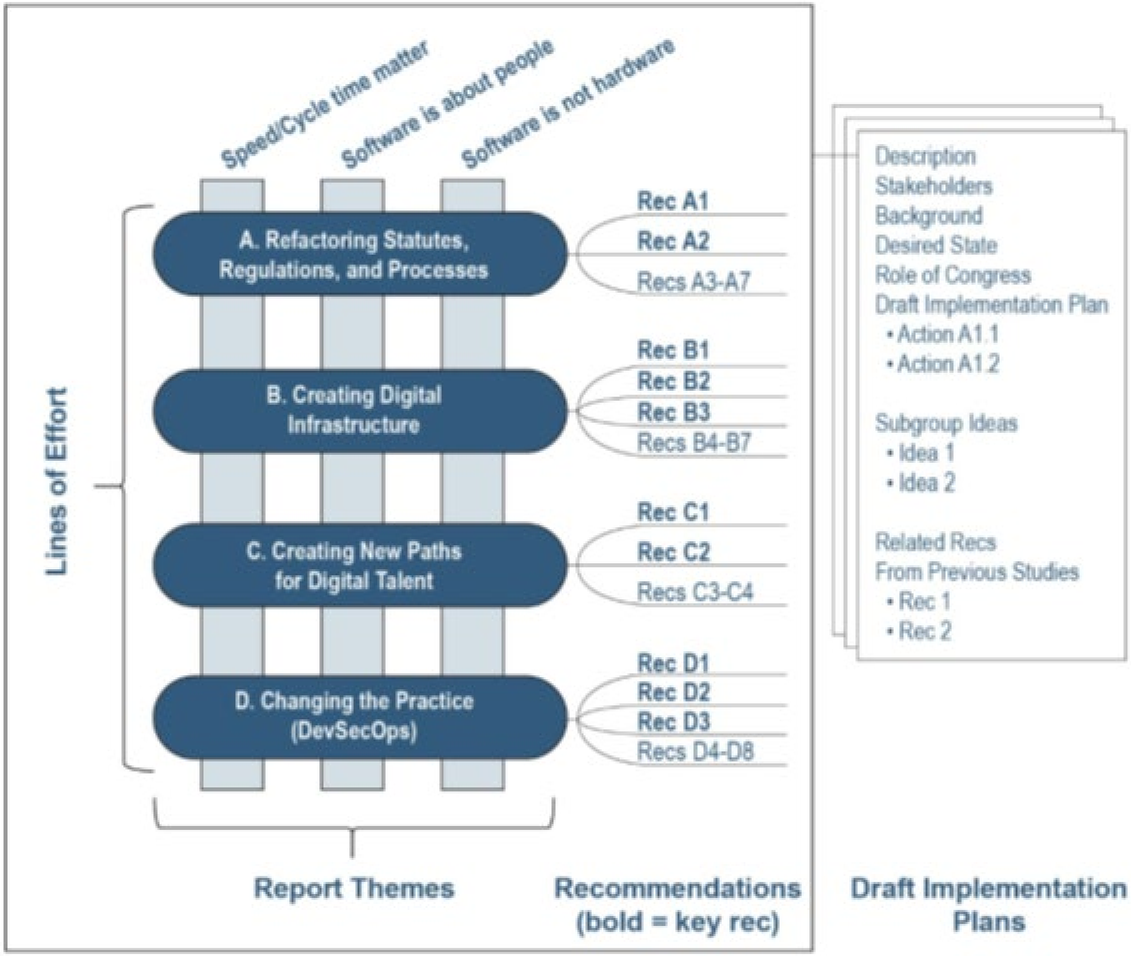

Figure 6. DIB SWAP Study Themes and LOEs. Source: DIB (2019).

LOE A is Congress's responsibility. The SWAP study identified that Congress owes it to the nation to pass new laws that make sense for software acquisitions. Additionally, Congress and the DoD must work together to create appropriate means of providing oversight to software programs under the new ways of authorizing expenditures on software acquisitions. LOEs B and C fall upon the secretary of defense and each service branch. The DoD itself needs to create a robust development and testing infrastructure that allows any software program to rapidly develop, test, and deploy new capabilities. This includes refining the JCIDS requirements process for software and determining at what point in development software is ready to be deployed to the operators. On the personnel side, an aging acquisition workforce whose leadership does not see the need to treat software acquisition different than hardware hampers reform. Additionally, the promotion system that emphasizes time employed over awarding high performers drives programmer talent away from the DoD and into private industry. LOE D recommends that the DoD continue to align with the industry best practice of using Development, Security, and Operations (DevSecOps) to structure its software development (DIB, 2019).

The overarching message of the SWAP study is summarized as follows, “The long-term consequence of inaction is that our adversaries’ software capabilities can catch and surpass ours. ... Our adversaries’ software capabilities are growing as ours are stagnating” (DIB, 2019, p. 28). Since 1982, various government and nongovernment agencies have issued reports emphasizing the importance of software’s role in maintaining a technological edge over adversaries, while at the same time pointing out that the DoD and Congress need to optimize the acquisition of software. Together, these entities have made 92 major recommendations and 231 sub-recommendations and have written almost 3,000 pages in reports urging change. Despite many calls for help, there has been little change in the way the DoD acquires software. The DIB recognized that the DoD remains tied to a traditional waterfall style acquisition strategy and the traditional budgeting and appropriations framework (DIB, 2019).

F. BUDGET ACTIVITY 8

As previously discussed, each program requires the assignment of a PE for funding to be appropriated for that program. While this system is useful in identifying and tracing specific funding by the trisection of appropriation category, MFP, and service component; appropriation categories are subdivided by Budget Activities (BAs), Activity Group, and Subactivity Group for further convenience of management, reporting, and oversight. DoD Financial Management Regulations Volume 2 is the governing reference for budget formulation and provides detailed guidance on the reporting and submission structures for each appropriation category. In this fashion, O&M appropriations are subdivided into four BAs (BA-1 Operating Forces, BA-2 Mobilization, BA-3 Training and Recruiting, and BA-4 Administrative and Service-wide Activities). Procurement is divided by type of platform or system (e.g., ship, aircraft, missiles, weapons, etc.) and has further subdivisions within each at the BA level. RDT&E, prior to 2021 was subdivided into seven BAs (BA-1 Basic Research, BA-2 Applied Research, BA-3 Advance

Technology Development, BA-4 Advance Component Development and Prototype, BA-5 System Development and Demonstration, BA-6 RDT&E Management Support, and BA-7 Operational System Development) (DoD, 2011). For example, in 2020 Maritime Tactical Command and Control (MTC2) O&M funding would fall under O&M BA-1 (Operating Forces), Activity Group: Combat Operations/Support, Subactivity Group: Combat Communications and Electronic Warfare, while MTC2's RDT&E funding would fall under RDT&E BA-5 (System Development and Demonstration).

As a 2021 pilot and ongoing initiative, RDT&E BA-8 was implemented and titled Software and Digital Technology Pilot Program. BA-8 is led by the OUSD(A&S) with the support of Congress, the services, and the Office of the Under Secretary of Defense (Comptroller). The pilot effort is meant to have a single appropriation for software and digital technology. The hope is that this single appropriation streamlines processes to match the more fast-paced technological development required in software acquisitions. The primary recommendation from the DIB is as follows: "Create a new appropriation category that allows (relevant types of) software to be funded as a single budget item, with no separation between RDT&E, production and sustainment" (DIB, 2019, p. 33). These pilot programs seek to accomplish this recommendation along with the faster technological development outlined as a priority in the interim National Security Strategic Guidance. BA-8 utilizes multiyear pilot programs to properly exercise a single appropriation.

G. BACKGROUND SUMMARY

After describing the major points behind the budget formulation and execution phases, the software acquisitions pathway, and the goals expressed in the SWAP study, it is now possible to appreciate some of the potential conflicts caused by the traditional method of funding when applied to the more agile software acquisitions. The overall goal in the development of the software pathway was to increase speed, reduce cycle time, and shift to a DevSecOps model of software development to have a more iterative development process. The rigidity of the budget formulation and execution process can be seen as another barrier preventing this framework from being utilized to its full potential. This is the barrier that the BA-8 pilot programs seek to address. With the creation of a single budget line item for the use of funds in this iterative process, software developers are hopefully more easily able to execute the process as intended.

The next chapter describes the data provided by the pilot program that is the subject of this analysis, the data from the NCSA control group, and the methodology for conducting the analysis of the effectiveness of this initiative.

III. DATA AND METHODOLOGY

The historical data for man-hours and delivery cadence included in the analysis of the Maritime Tactical Command and Control (MTC2) program is provided by the MTC2 team. As part of the BA-8 pilot program, MTC2 is also subject to the submission of quarterly reports to Congress that serves as part of the analysis (OUSD[A&S], 2021). The MTC2 team also provided qualitative data in the form of answers to questionnaires, challenges and successes experienced by the program regarding the BA-8 pilot, and the BA-8 pilot's monthly service update. Similarly, Navy Cybersecurity Awareness (NCSA) provided budget man-hour data, albeit with less historical data, and provided qualitative data in the form of the same survey forms provided by the MTC2 team. Additionally, the funds allocated to MTC2 and NCSA in the federal budget provides data to perform a cost analysis. This chapter displays the provided data and explains the methodology that the researchers used to analyze this data to answer the research questions and determine the effectiveness and cost savings that the BA-8 pilot provides.

A. MARITIME TACTICAL COMMAND & CONTROL DATA

The following is the data provided by the MTC2 team. This includes data on the man-hours required for budget formulation, cadence information based on feature completion dates, and program cost data. Qualitative data provided by the team is addressed in the analysis section.

1. Budget Man-Hour Data

The MTC2 budget team man-hours are distributed by program elements (PEs), and the amount of time generating the budget was directly affected by the implementation of the BA-8 pilot initiative. Tables 1–3 display the FY2020–FY2022 man-hour data provided by MTC2. These man-hours describe the amount of time to formulate the budget, not by the entire program office.

Table 1. FY2020 MTC2 Budget Exhibits. Adapted from Maritime Tactical Command and Control (MTC2, personal communication, September 23, 2022).

Appropriation	Program Element	Hours
RDT&E	0604231N	32.58
O&M	0204660N	3.44
	BOCs[a]	2.50
	IT Exhibits[b]	0.08
Total:		38.60

[a]BOCs – Budget Object Codes used in posting of transactions.

[b]IT Exhibits – Information Technology Exhibits.

Table 2. FY2021 MTC2 Budget Exhibits. Adapted from MTC2 (personal communication, September 23, 2022).

Appropriation	Program Element	Hours
RDT&E	0608231N (BA-8)	28.38
~~RDT&E~~	~~0604231N~~	
O&M	0204660N	0.50
	BOCs	2.50
	IT Exhibits	0.00
Total:		31.38

Table 3. FY2022 MTC2 Budget Exhibits. Adapted from MTC2 (personal communication, September 23, 2022).

Appropriation	Program Element	Hours
RDT&E	0608231N (BA-8)	11.16
~~RDT&E~~	~~0604231N~~	
~~O&M~~	~~0204660N~~	
	BOCs	3.00
	IT Exhibits	2.00
Total:		16.16

The PE is described by MTC2 (personal communication, September 23, 2022) as the foundation of the Planning, Programming, Budgeting, and Execution (PPBE) process. Each program entity has its own PE to allocate resources within the Office of the Secretary of Defense. The 0604231N and 0204660N PEs are part of the RDT&E and O&M funds respectively. However, in FY2021 the MTC2 team started the transition to BA-8 funding. This is the reason for the 0608231N (BA-8) PE in FY2021 and FY2022.

Even though it is labeled RDT&E, the BA-8 appropriation allows the software to be funded as a single budget item. The PEs that are stricken from the tables are meant to display the PEs that are no longer required after transition to BA-8. Additionally, some of the hours in the FY2022 budget are based on a projected President's budget.

2. Delivery Cadence Data

The data on delivery cadence was provided by the MTC2 development team in the form of lead time data. Using the date that the first feature of their software was completed, the date the last feature was completed, and the date that the project was approved by the Fleet Readiness Certification Board (FRCB), the average, minimum, and maximum lead time was calculated (MTC2, personal communication, September 23, 2022). These data are displayed in Table 4.

Table 4. MTC2 Project Development Lead Times and Dates. Adapted from MTC2 (personal communication, September 23, 2022).

	Development 1	Development 2
Date First Feature Completed:	7/30/2020	4/12/2021
Date Last Feature Completed:	4/8/2021	1/27/2022
Midpoint between First/Last Feature Completed:	12/3/2020	9/4/2021
Date of FRCB Approval:	9/8/2021	8/4/2022
Average Lead Time for Change (Days):	279	334
Minimum Lead Time for Change (Days):	153	189
Maximum Lead Time for Change (Days):	405	479

3. Cost Data

The cost data for the MTC2 program comes from the Federal Budget for FY2020–FY2022. In FY2020, the program was utilizing traditional O&M and RDT&E funding. In FY2021, they were in their "new start" for BA-8 funding. Following that, in FY2022, MTC2 had fully transitioned into the BA-8 funding. The costs are summarized in Table 5.

Table 5. FY2020–FY2022 Federal Budget Costs. Adapted from Department of the Navy (2021a, 2021b, 2022).

Fiscal Year	Appropriation	Cost ($ in Thousands)
2020	O&M	4,303
	RDT&E	10,270
	RDT&E (BA-8)	0
	Total:	14,573
2021	O&M	0
	RDT&E	0
	RDT&E (BA-8)	10,969
	Total:	10,969
2022	O&M	0
	RDT&E	0
	RDT&E (BA-8)	14,843
	Total:	14,843

Note. FY2020 and FY2021 dollar amounts are not adjusted for inflation.

4. Qualitative Data

The qualitative data provided by the MTC2 team are addressed in the next chapter to adequately provide recommendations for each challenge that was faced and to recognize the challenges and successes that the MTC2 team experienced in the implementation of BA-8 funding.

B. NAVAL CYBERSECURITY AWARENESS DATA

Like MTC2, the NCSA team provided budget man-hour data to aid in analysis of the effectiveness of the use of BA-8 funding by comparing the MTC2 program to one using traditional funding. Additionally, NCSA provided comments and questionnaires to provide insight into the qualitative aspects of the use of colorless appropriations.

1. Budget Man-Hour Data

NCSA provided budget man-hour data for the budgeting team, which is summarized in Table 6. However, FY2022 was the only year data were available for analysis. Much like the MTC2 data, these data are separated by PE and display the type of appropriation that is associated with that PE as they were utilizing traditional funding as opposed to BA-8 colorless appropriations.

Table 6. NCSA FY2022 Budget Exhibits. Adapted from Naval Cybersecurity Awareness (NCSA, personal communication, September 29, 2022).

Appropriation	Program Element	Hours
OPN	3415	14.00
RDT&E	0303140N	8.00
O&M	1CCY	1.50
	BOCS	1.00
	IT Exhibit 300 CND	0.50
	IT NC36	3.50
	Total:	28.50

NCSA also noted that they would expect budget hours to fall to around 18 hours if under a single BA-8 appropriation.

2. Delivery Cadence Data

NCSA was unable to provide data on delivery cadence; therefore, all analysis is conducted using the data provided by MTC2. This is addressed further in the next chapter in the recommendations portion of the results.

3. Cost Data

Unlike the MTC2 program, NCSA was never allocated to the BA-8 funding, so all cost data are under the traditional funding. Therefore, the cost data for the NCSA program are not necessary for the purpose of this analysis.

4. Qualitative Data

NCSA also provided some recommendations and insight in the same format that was provided by MTC2. Each of these are addressed in the qualitative analysis in Chapter IV, Section F.

C. COST-EFFECTIVENESS ANALYSIS

Any problem associated with making a budget decision within the DoD requires analysis of multiple variables, each with their own units of measure and a cost for each line item (see Circulars A-4 and A-94 for details). The complicated and important nature of this problem demands a methodological problem-solving approach to ensure that tax dollars are being spent wisely. When multiple variables are present, researchers use a technique called multiple objective decision-making to make recommendations. This process is described in detail in the third part of the 2015 book titled *Military Cost–Benefit Analysis*, written by K. D. Wall and C. A. MacKenzie, which serves as the backbone of the methodology behind the cost-effectiveness portion of this analysis.

According to Wall and MacKenzie , each variable that is not money is subjected to an effectiveness analysis, which yields a unitless measure of effectiveness (MOE). This MOE is then compared to cost to guide decision-makers to the most cost-effective option that accomplishes the mission (Wall & MacKenzie, 2015). To provide an example of the process of cost-effectiveness analysis, this section will use the fictitious example of deciding between purchasing two sports cars, Car A and Car B, utilizing a multiple objective decision-making framework which is comparable to the deciding between traditional and colorless funding.

1. Determine Objectives and Alternatives

Wall and MacKenzie described the first step in determining a MOE to be determining the objectives and alternatives of the cost-effectiveness analysis (CEA). Alternatives are the number of available decisions that can be made. In this example, one can choose to either purchase Car A or purchase Car B. Therefore, there are a total of two alternatives from which to choose, much like the analysis of traditional and BA-8 funding. Within each alternative, there are multiple performance metrics that could affect the ultimate purchase decision. These metrics are what Wall and MacKenzie described as objectives (Wall & Mackenzie, 2015).

In the case of a CEA, the objectives that are used in the calculations need to be measurable (Wall & Mackenzie, 2015). There are multiple ways of determining measurable objectives, but the method that is relevant to this case is a top-down approach. Applying the top-down approach to the car purchasing decision, the obvious goal is to find out which vehicle is the most effective. However, many variables determine a car's overall effectiveness. General categories one might consider for a sports car's overall effectiveness are the 0–60 acceleration time, fuel-efficiency, and the turning radius. Furthermore, regarding the fuel efficiency category, there is also a difference between highway and city fuel efficiency. Determining the objectives and categorizing them continues with the development of what Wall and MacKenzie referred to as an objective hierarchy, which, for the car example, is displayed in Figure 7 (Wall & Mackenzie, 2015).

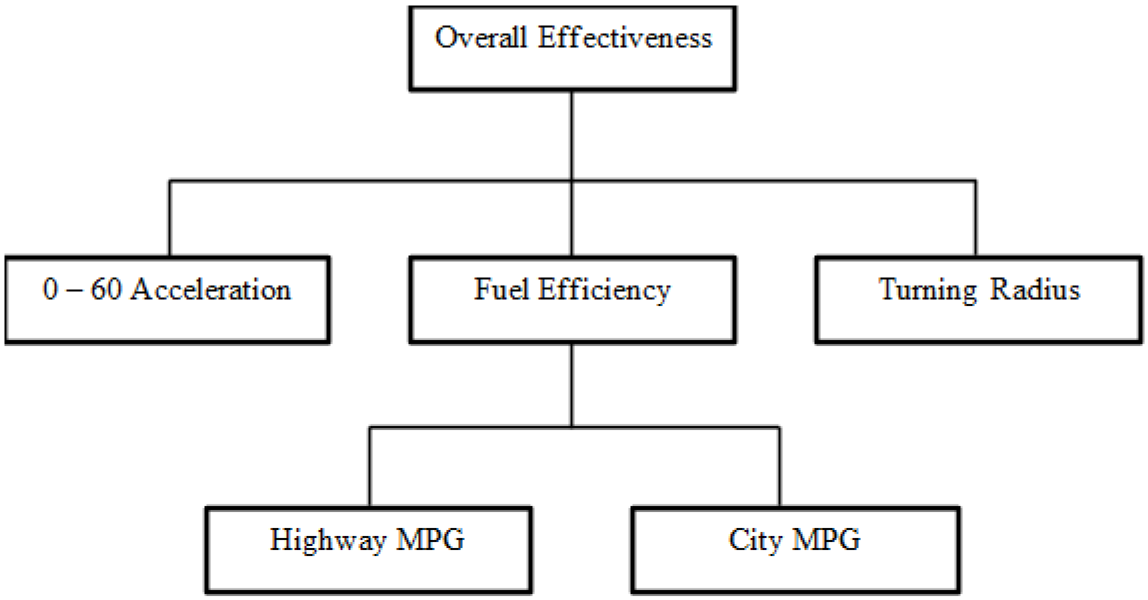

Figure 7. Example Objective Hierarchy for a Sports Car

The objectives at the termination of each branch of the objective hierarchy are all measurable: acceleration in seconds, turning radius in feet, and miles per gallon. Wall and MacKenzie emphasized that measurability is crucial in determining objectives, but to compare them, one must achieve commonality amongst them (Wall & Mackenzie, 2015). The next part of the analysis strives to achieve this commonality for comparison.

2. Deriving Value Functions

To reach the next phase of analysis, Wall and MacKenzie explained that each objective has a marginal value associated with each step up in performance, with this marginal value of each next level of performance being highly affected by the buyer's preference. To start, Wall and MacKenzie stated that one must determine if the desire is to maximize or minimize the objective and then break each objective into increments. In the case of highway fuel efficiency, fuel efficiency should be maximized, and this objective might be broken into 3 miles-per-gallon (MPG) increments. The buyer then starts at 0–3 MPG and determines the incremental value of this segment on a scale of 0 to 10, where 0 indicates not important at all and 10 indicates the utmost importance. This process is repeated for each increment of 3 MPG until no more realistic value is gained from this objective. The sum of each increment's value is then taken, and each increment is divided by this sum. The resulting values are what Wall and MacKenzie referred to as the cumulative values (Wall & Mackenzie, 2015). The process of prescribing incremental and cumulative values in the example of MPG in the car example is pictured in Table 7.

Table 7. Example Value Functions for Highway MPG

Highway MPG	Marginal Increment Value (0–10)	Cumulative Value (0–1)
0–3 MPG	10	0.137931034
3–6 MPG	10	0.137931034
6–9 MPG	10	0.137931034
9–12 MPG	10	0.137931034
12–15 MPG	9	0.124137931
15–18 MPG	8	0.110344828
18–21 MPG	6.5	0.089655172
21–24 MPG	4	0.055172414
24–27 MPG	3	0.04137931
27–30 MPG	1	0.013793103
30–33 MPG	0.5	0.006896552
33–36 MPG	0.5	0.006896552
36–39 MPG	0	0
Sum:	72.5	1

Using a graph of the cumulative values, a best fit line over a histogram yields what is defined by Wall and MacKenzie as the value function, v(j) (Wall & Mackenzie, 2015). This is displayed in Figure 8.

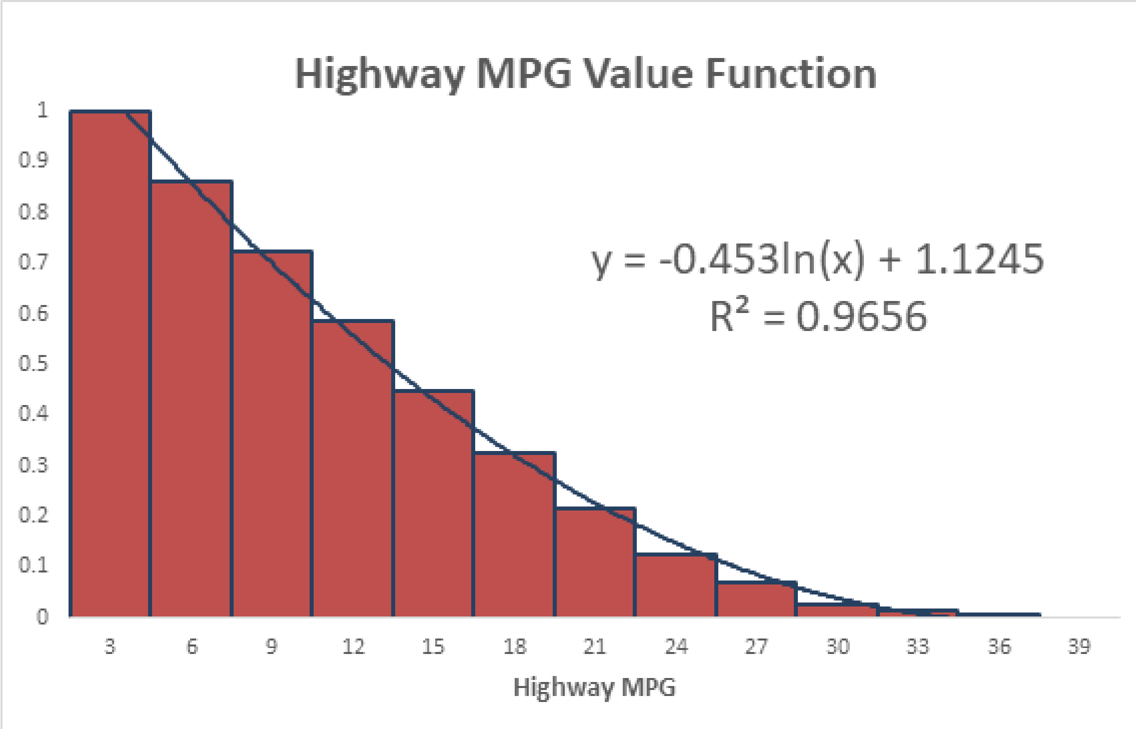

Figure 8. Highway MPG Value Function

3. Relative Weight of Objectives

The next step in the process is to assign a relative weight of importance to each objective in the analysis. There are many ways to approach this problem. The most straightforward approach is the direct assessment method. In this approach, the analysis relies on the decision-maker to assign the relative weights . The direct approach is useful when there are few objectives, or the relative importance of each objective is obvious (Wall & MacKenzie, 2015). This analysis utilizes the direct assessment method.

In cases where there are many objectives, Wall and MacKenzie showed that a more comprehensive method is needed. The additional methods described by Wall and MacKenzie include equal importance, rank sum and rank reciprocal, swing weighting, and pairwise comparison. In the case of equal importance, the decision-maker has specified that every objective is equally important . The rank sum and rank reciprocal method is used when the objectives are clearly defined as the most important, second-most important, and so on . Swing weighting allows for a weighting method that is sensitive to where an alternative's objective value lies along the range of possible values, which is accomplished by letting all objective values equal zero . At this point, Wall and

MacKenzie stated that the decision-maker decides which objective, if taken from its minimum to maximum value, provides the most benefit, subsequently giving a relative value of 100. The process is then repeated for each objective while the others are held constant at 0, and all relative values are summed and divided by the sum to yield the objective's relative weight . Pairwise comparison is just a simpler version of swing weighting (Wall & MacKenzie, 2015). In the case of the analysis of MTC2, there will be two objectives, yielding a pairwise comparison approach.

4. Calculating the Measure of Effectiveness

Once the value functions for each objective and their relative weights have been determined, the last step in determining the MOE for each alternative is combining the values and objectives (Wall & MacKenzie, 2015). The same part of Wall and MacKenzie's 2015 book displays how each objective value function is multiplied by its weight and the product of each piece is summed together to form the equation below for the overall effectiveness of an alternative.

$$v(j) = w_1 * v_1\big(x_1(j)\big) + w_2 * v_2(x_2(j))$$

This overall effectiveness is then used to develop an MOE for each of the alternatives in the analysis.

5. Integrating Cost

Once the MOE has been determined, researchers must then factor in the element of cost . This is accomplished by taking the projected total ownership cost for an alternative, discounting the cost, and graphically representing cost on the x-axis versus overall MOE on the y-axis . This graph gives the decision-maker an easily interpretable picture that shows the costliest option, the option that yields the highest effectiveness per dollar of cost, and many other important results depending on the situation (Wall & MacKenzie, 2015). See Figure 9 for an example of the cost versus overall effectiveness graph for the sports car example.

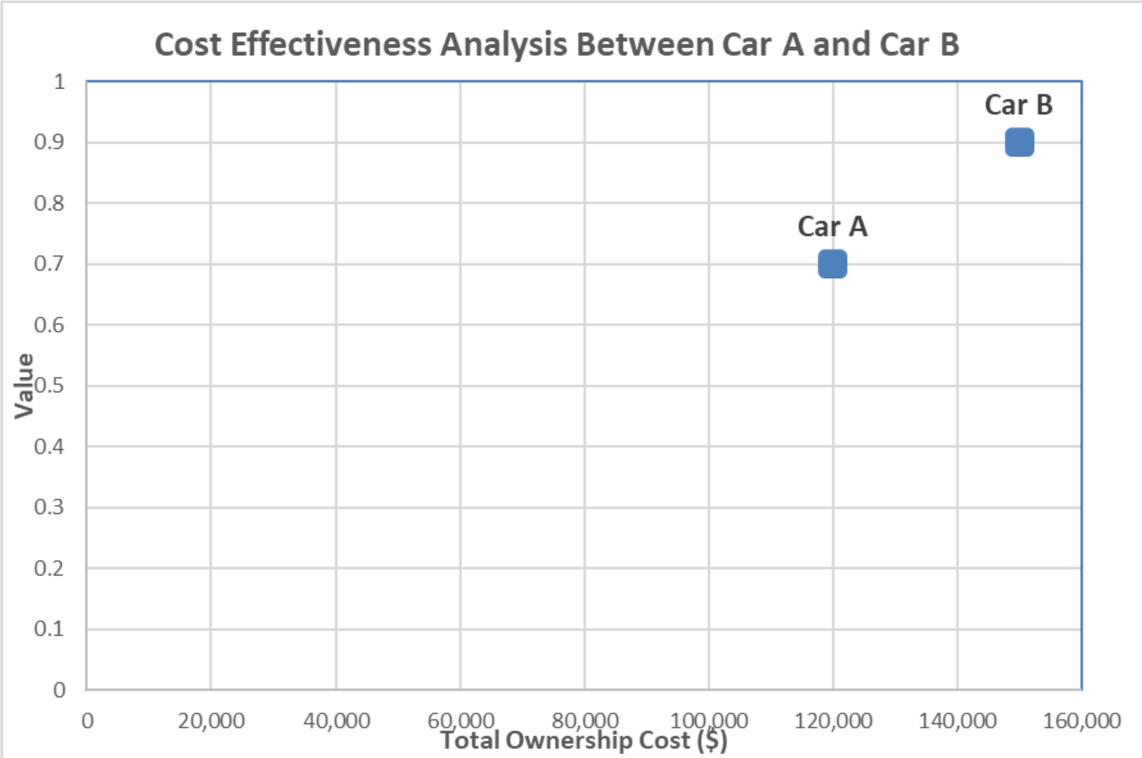

Figure 9. Cost-Effectiveness Analysis between Car A and Car B

D. DATA AND METHODOLOGY SUMMARY

The small scope of the pilot and limited time frames for analysis narrows the scope of the data available for analysis. Despite this, the MTC2 and NCSA programs have collected the data necessary to make a preliminary analysis of the effectiveness of BA-8 authorization for software programs, a cost analysis conducted from before and after the transition, and an analysis of the provided qualitative data. Using a multiple objective decision-making model to determine overall MOE and compare this to cost, the researchers determined the value of using BA-8 for the past 3 FYs of the software pilot programs. The next chapter utilizes the previously discussed data for a CEA and cost analysis, followed by some recommendations regarding both the CEA and qualitative aspects of the information provided by these programs.

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IV. ANALYSIS AND RECOMMENDATIONS

This chapter contains a CEA of the BA-8 single appropriation line item, or colorless money, in comparison to the traditional funding under multiple appropriations. In the objective hierarchy, cadence and budget man-hours were selected based on the expected impact BA-8 was anticipated to have and the availability of recorded metric data. The value function for each attribute is formulated, and value weighting is assigned. Value weighting is typically informed by the decision-maker, who will ultimately utilize the CEA in selecting the alternative to pursue. For this research, the researchers consulted with Captain (Ret.) Jeffery Dunlap, a retired naval officer with 25 years of operational, acquisition, and program management experience and 8 years of industrial base and DIB experience. Dunlap is a lecturer at the Naval Postgraduate School in acquisition management with a focus in software acquisition. Using the information provided by Dunlap, the researchers assigned value functions and weights and developed the MOE score for each alternative. These MOEs are then plotted against their associated costs to output a graphical representation of the cost-effectiveness. In this case, two alternatives are compared, MTC2's MOE with traditional appropriation versus the MOE under single appropriation (BA-8). The result will demonstrate how much more or less effective the program was and for what cost. Beyond the quantitative MOE score and CEA derived solution, the qualitative challenges and successes captured by both the MTC2 and NCSA teams are discussed. Finally, recommendations based on the results and data are considered.

A. OBJECTIVE HIERARCHY

The overall effectiveness of a software acquisition program can be assessed from several angles. The limited range of data available for review affects the breadth to which this analysis can be conducted, which will be discussed later in the recommendations section. Focusing on the available data, the first level in the objective hierarchy this research identified is speed of delivery, from identification of requirement to delivery to the end user, and the time and resources spent in doing so. However, these objectives are not easily quantified. Taking another step down the hierarchy, two measurable objectives can be identified. Cadence of software updates and budget man-hours were measurable and relevant metrics by which to assess speed of delivery and time consumed. For the sake of calculations, let cadence be defined as x_1 and budget man-hours be defined as x_2. This objective hierarchy is depicted in Figure 10.

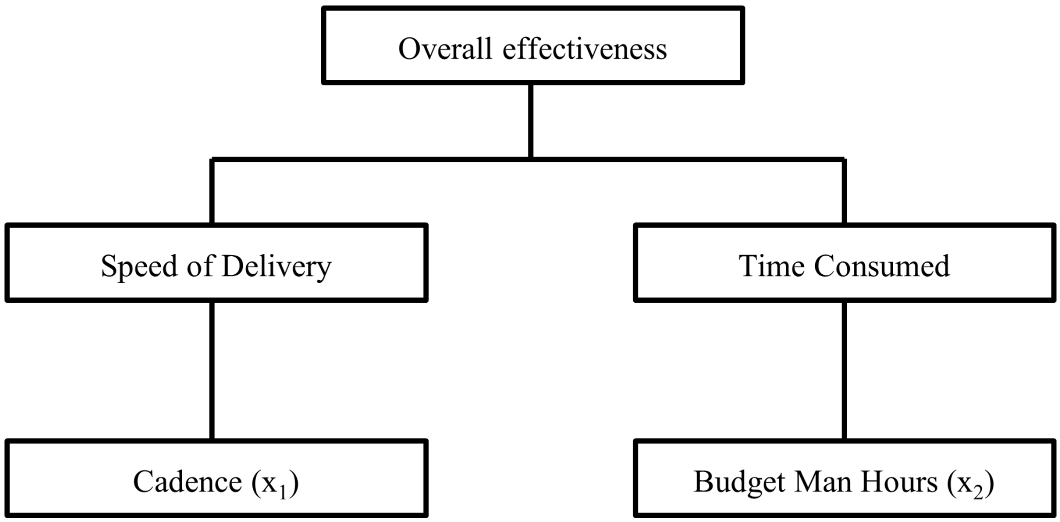

Figure 10. BA-8 Objective Hierarchy

B. VALUE FUNCTIONS

In this section functions are developed for both previously described objectives. The development of these functions is based on input from CAPT (Ret.) Jeffery Dunlap and serve as the basis of the analysis of the MOE of MTC2 before and after implementation of BA-8 funding.

1. Cadence Function

Cadence (x_1) is best defined as deliveries per unit of time. As such, the most efficiency is gained when cadence is maximized. For this analysis, cadence is broken up into month-long increments. The relative value on a scale from 0 to 1 of each increment was determined in an interview with CAPT (Ret.) Jeffery Dunlap on November 15, 2022. Based on his experience in software acquisitions and analysis of the timeline of delivery for the MTC2 program, it was determined that, for a program which has demonstrated its minimum viable capability release (MVCR) and had progressed into a planned delivery schedule, the aim for development completion is 6 months into a cycle (J. Dunlap, interview with authors, November 15, 2022). The 6-month goal would allow time for testing to receive authority to operate (ATO, a post-development process to validate software compliance and integration within existing DoD networks), and the resulting development plus ATO time would ideally take about 9 months, leaving room for a buffer (J. Dunlap, interview with authors, November 15, 2022).

These timelines are based on a value to the operator coupled with a business requirement to plan for development release and the associated ATO offset. Value to the operator for an emergent requirement can be expressed as an exponential decay function. That is, if an emergent requirement is identified now, it is of high value to the operator to have that solution immediately to address the problem that this requirement was derived from. That same solution holds significantly less value in a month. The month after, it holds even less value, and so on, approaching but not reaching zero, because the solution will still hold some value even it is delivered a year from now (J. Dunlap, interview with authors, November 15, 2022). A graphical representation of value to the operator is found in Figure 11.

Under the current software development and testing architecture, the ATO can be expected to take an average of 3 months (J. Dunlap, interview with authors, November 15, 2022). At this point, value to the operator has already dropped by more than half. Therefore, for a PM, executing at high velocity and developing a solution within a month still provides less than half of the value to the operator. Instead, under these conditions, a moderate pace of development (targeting 6 months) only loses marginal value to the operator without significantly increasing costs and maintaining planning stability within the program and development office. Combining the two distributions for development and development plus ATO yielded a target average of 7.5 months for the ideal program to develop software, pass ATO, and release a minimal viable product to the warfighter. This is the target delivery cadence that provides the most value to the decision-maker. Faster delivery would increase costs and not appreciably improve value to the operator, and slower delivery approaches the 12-month mark, beyond which a software acquisition program is considered broken and likely to be cancelled. To the software acquisition decision-maker, the value of delivery cadence can be considered a bell curve centered around the 7.5-month target timeline (J. Dunlap, interview with authors, November 15, 2022). A graphical representation of these results is found in Figure 12.

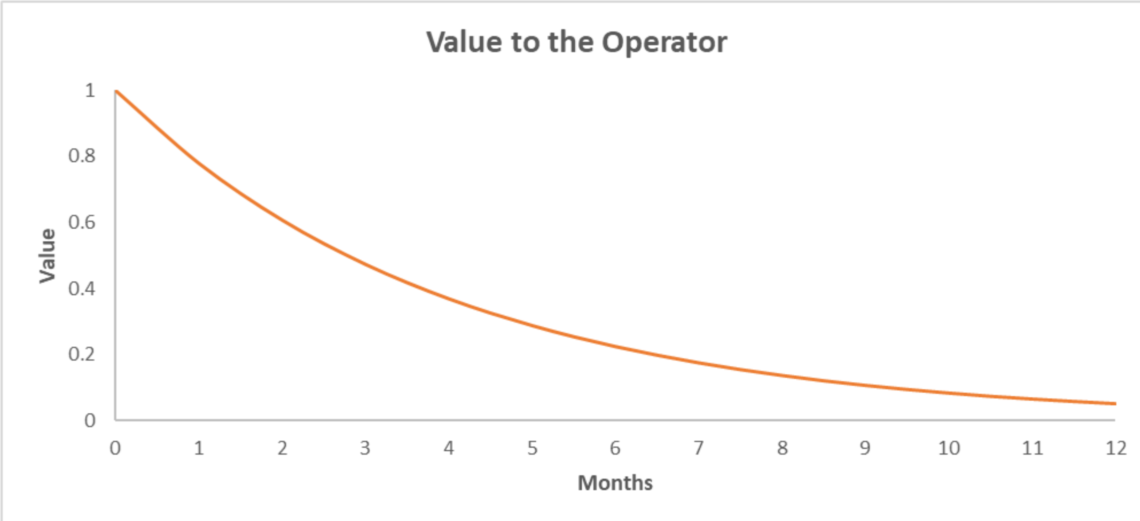

Figure 11. Value to the Operator

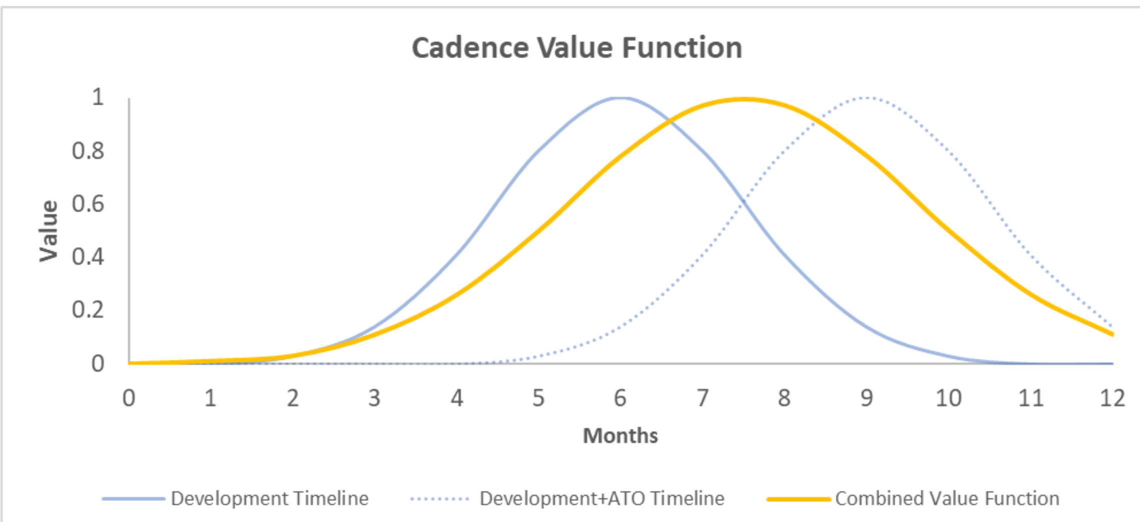

Figure 12. Cadence Value Function

Using the combined value function, the average time to complete a development cycle (μ) is 7.5 months, and the standard deviation of this distribution (σ) is 2.12132034. Using the generic equation for a normal distribution with these values for μ and σ yields this cadence value equation ($v_1(x_1(j))$). To evaluate programs on a 1 to 1 scale, a scaling factor was applied to scale the normal distribution such that a cadence equal to the mean target value of 7.5 outputs a cadence value of 1.

$$v_1\left(x_1(j)\right) = \frac{1}{2.12132034\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-7.5}{2.12132034}\right)^2} \times Scaling\ Factor$$

$$Scaling\ Factor = \frac{1}{\frac{1}{2.12132034\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{7.5-7.5}{2.12132034}\right)^2}}$$

2. Budget Man-Hour Function

The second objective is budget man-hours, $v_2(x_2(j))$, which is a simple measurement of the number of hours a program office spent formulating their budget per FY. As determined in the interview with CAPT (Ret.) Jeffery Dunlap (interview with authors, November 15, 2022), any budget office man-hours saved developing budgets under BA-8 can be applied elsewhere in the financial management of a program, making any improvement hold a value of 1 on a scale of 0 to 1. The hours spent on the traditional funding budget in FY2020 were set at a value of 0. This will exaggerate the effect of man-hours saved within this objective. However, the low value of this objective's weight will compensate for this offset. Objective weights are discussed in the next section. No equation was derived for this objective; however, a graphical representation of this step function is depicted in Figure 13.

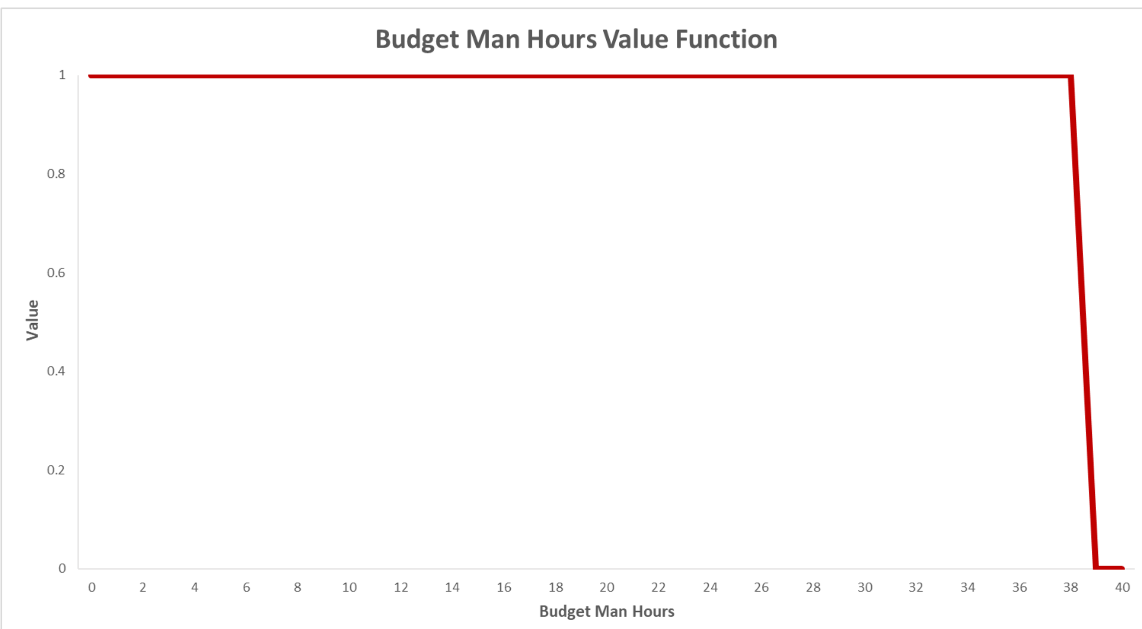

Figure 13. Budget Man-Hours Value Function

C. IMPORTANCE WEIGHTS

This research utilized a direct assessment approach to determine the relationship between cadence and budget man-hours based on consultation with acquisition professionals. This was possible due to only having two objectives and the understanding that budget man-hours were only a small portion of the overall effort that goes into acquiring software programs. Based on an interview with CAPT (Ret.) Dunlap (J. Dunlap, interview with authors, November 15, 2022), the time spent on formulating the budget is a small fraction of the overall effort that goes into a software program. Additionally, as determined in the same interview, delivering capability to the warfighter is the penultimate goal of any acquisition program (J. Dunlap, interview with authors, November 15, 2022). Therefore, the cadence objective weight (w_1) was determined to be 0.99, and the budget man-hours objective weight (w_2) was set at 0.01. Sensitivity to cadence weight (with budget man-hour weight being 1 minus cadence weight) and target cadence is shown in Table 8. Sensitivity to cadence weight and actual cadence is shown in Table 9.

Table 8. Cadence Weight & Target Cadence Sensitivity

	MOE	Cadence Weight										
	0.853622	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Target Cadence	1	1	0.904411	0.808822	0.713232	0.617643	0.522054	0.426465	0.330876	0.235287	0.139697	0.044108
	2	1	0.912816	0.825633	0.738449	0.651266	0.564082	0.476898	0.389715	0.302531	0.215348	0.128164
	3	1	0.92982	0.859639	0.789459	0.719279	0.649099	0.578918	0.508738	0.438558	0.368378	0.298197
	4	1	0.955556	0.911112	0.866668	0.822224	0.77778	0.733336	0.688892	0.644448	0.600004	0.55556
	5	1	0.98288	0.96576	0.94864	0.93152	0.914399	0.897279	0.880159	0.863039	0.845919	0.828799
	6	1	0.999005	0.99801	0.997015	0.99602	0.995025	0.99403	0.993035	0.99204	0.991045	0.99005
	7	1	0.994701	0.989402	0.984103	0.978804	0.973506	0.968207	0.962908	0.957609	0.95231	0.947011
	8	1	0.972534	0.945069	0.917603	0.890137	0.862671	0.835206	0.80774	0.780274	0.752808	0.725343
	9	1	0.944486	0.888972	0.833457	0.777943	0.722429	0.666915	0.611401	0.555886	0.500372	0.444858
	10	1	0.921847	0.843694	0.765541	0.687388	0.609235	0.531081	0.452928	0.374775	0.296622	0.218469
	11	1	0.908591	0.817182	0.725773	0.634364	0.542955	0.451547	0.360138	0.268729	0.17732	0.085911
	12	1	0.902705	0.80541	0.708116	0.610821	0.513526	0.416231	0.318936	0.221641	0.124347	0.027052

Table 9. Cadence Weight & Cadence Sensitivity

	MOE	Cadence Weight										
	0.853622	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Cadence	2	1	0.90347	0.806939	0.710409	0.613879	0.517348	0.420818	0.324288	0.227757	0.131227	0.034697
	4	1	0.925638	0.851275	0.776913	0.70255	0.628188	0.553825	0.479463	0.405101	0.330738	0.256376
	6	1	0.97788	0.95576	0.93364	0.91152	0.8894	0.86728	0.845161	0.823041	0.800921	0.778801
	8	1	0.99726	0.994521	0.991781	0.989042	0.986302	0.983563	0.980823	0.978084	0.975344	0.972604
	10	1	0.949935	0.89987	0.849806	0.799741	0.749676	0.699611	0.649546	0.599481	0.549417	0.499352
	12	1	0.91054	0.82108	0.73162	0.64216	0.5527	0.46324	0.373779	0.284319	0.194859	0.105399
	14	1	0.900915	0.801829	0.702744	0.603658	0.504573	0.405488	0.306402	0.207317	0.108231	0.009146
	16	1	0.900033	0.800065	0.700098	0.600131	0.500163	0.400196	0.300228	0.200261	0.100294	0.000326
	18	1	0.9	0.800001	0.700001	0.600002	0.500002	0.400003	0.300003	0.200004	0.100004	4.79E-06
	20	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	2.89E-08
	22	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	7.15E-11
	24	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	7.29E-14

D. MEASURE OF EFFECTIVENESS SCORE AND COST-EFFECTIVE SOLUTION

With all the variables of the overall value function defined, the only step remaining is to calculate the overall value of each alternative. For cadence, the number of days between *Date Last Feature Completed* and *Date of FRCB* (Fleet Readiness Certification Board) *Approval* from Table 4 was used to determine the minimum cycle time for integration to fielding. This was used as the variable in the cadence value function. For Budget Man-Hours, the number the total number of hours spent on budget formulation is drawn from Tables 1 and 3. The formula and calculations for each alternative are pictured in Table 10.

$$v(j) = w_1 * v_1(x_1(j)) + w_2 * v_2(x_2(j))$$

Table 10. Measure of Effectiveness Calculation

Alternatives		=	Cadence Weight	*	Cadence Value Function for Alternative	+	Man Hour Weight	*	Man Hour Value Function for Alternative	=	Overall MOE
MTC2 Before	v(1)	=	0.99	*	0.527292424	+	0.01	*	0	=	0.5220195
MTC2 After	v(2)	=	0.99	*	0.852143789	+	0.01	*	1	=	0.853622351

E. COST ANALYSIS

With the overall MOE for each alternative determined, the final step in this cost-effectiveness analysis is comparing cost to MOE for each alternative. The costs are averages based on the budget prior to BA-8 funding within the MTC2 program and after. The results of this comparison are presented in Figure 14.

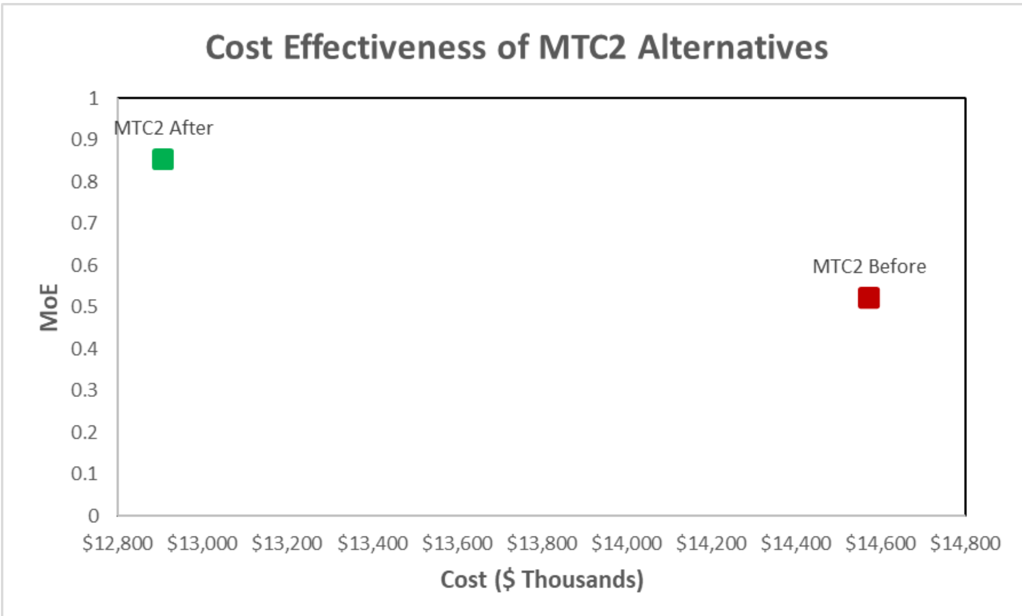

Figure 14. Cost-Effectiveness of MTC2 Alternatives

The scatterplot of the two alternatives shows an increase in effectiveness at a lower cost. It is important to note however, that the MTC2 cadence post-BA-8 was slower than prior to BA-8. The increased MOE, however, is driven by the target cadence and cadence weights, where post-BA-8, MTC2 performed closer to the target of 7.5 months. Additionally, with the limited data to compare, it is not possible to differentiate direct impact of BA-8 on cadence from normal variance. That is, the program office could be under several different factors and influences impacting cadence that are not reflected in the available data and cannot be accounted for via statistical methods given the limited data set.

F. QUALITATIVE DATA

Both the MTC2 team and NCSA teams provided information on qualitative aspects of the implementation of BA-8 funding. This information was provided in the form of questionnaires and their individual comments on the challenges and successes they experienced throughout implementation. This provides insight into some of the aspects of the BA-8 program that may be improved for greater effectiveness of the program in the future.

1. Challenges

One of the challenges faced by the MTC2 team in the implementation of a single appropriation was executing during a Continuing Resolution (CR). Immediately following the transition to BA-8, MTC2 was considered a "new start" program and was not authorized to execute funds with its new BA-8 appropriation during this CR (MTC2, personal communication, September 23, 2022). During a CR, however, existing programs are authorized to execute at the rate of the prior FY. Therefore, MTC2 was forced to execute funds from its prior FY PE during this CR, which required additional labor on the part of the budgeting team (MTC2, personal communication, September 23, 2022). Furthermore, once the appropriation bill was signed in February of that FY, the budgeting team then had to transfer the costs from the old PE to the new BA-8 PE, which, in turn, caused delays and created additional work for the program and budget office (MTC2, personal communication, September 23, 2022). While transferring these costs from the old PE to the new BA-8 PE, the MTC2 team then faced the challenge of possibly receiving a potential under execution mark (MTC2, personal communication, September 23, 2022). The CR, therefore, caused many issues within the budgeting process of that first pilot year. These challenges were unique to pilot programs in this set of circumstances; nonetheless, they created delays despite the goal being an effort to determine the potential time- and effort-saving benefits that the BA-8 program can provide.

Another challenge addressed by the MTC2 team was that due to the BA-8 program being a new program, the exhibits require more explanation because many DoD contractors and financial management professionals are unfamiliar with the existence of BA-8 and the unique set of rules BA-8 requires (MTC2, personal communication, September 23, 2022). The colorless appropriation does not follow the traditional method that many outside the program are used to, which created difficulties in implementing the funding, especially in the realm of contracting.

Finally, due to the relative infancy of the program, it was difficult for MTC2 to demonstrate benefits to delivery of capabilities and increased cadence (MTC2, personal communication, September 23, 2021). Having recently delivered its MVCR prior to transitioning into the BA-8 pilot and executing its second delivery increment, the first under BA-8, there simply is insufficient delivery history to demonstrate any statistically relevant change to delivery cadence. In the future, MTC2 seeks to deliver software on a more regular cadence to the fleet, at which point the data may be able to display more of the benefit of BA-8 funding.

As for the NCSA team, the questionnaire filled out by their team recognized that BA-8 is perceived as not very helpful in the categories of contracting and engineering. Specifically, NCSA (personal communication, September 29, 2022) found it difficult to assess how BA-8 would affect contract management without more information on how the appropriation would be utilized in contracting. These perceived challenges were like those experienced by MTC2 operating under BA-8 (MTC2, personal communication, September 23, 2022). These challenges and uncertainties were noted by NCSA (personal communication, September 29, 2022) as a major decision factor in declining to participate in the BA-8 pilot.

2. Successes

MTC2 (personal communication, September 23, 2022) recognized combining the appropriations into a single appropriation category does indeed streamline execution and make it easier to fund contracts. However, this is with the assumption that there is not a CR causing complications in the use of the appropriation in that FY. This is important as it addresses one of the major concerns when using multiple appropriations in software development, which is the time the entity spends on realigning and monitoring funds within the PE—causing a backlog, more work for the budgeting team, and delays in execution. Additionally, MTC2 (personal communication, September 23, 2022) anticipates that programs with a well-developed delivery cadence but are constrained by funding categories would likely experience measurable benefits if transitioned to a single appropriation.

The NCSA team echoed many of the points that were recognized by the MTC2 team. NCSA (personal communication, September 29, 2022) recognized that integration of BA-8 funding would lower man-hours required in the budgeting office to around 18 hours, giving workers time for additional tasks. Additionally, the questionnaire filled out by NCSA (personal communication, September 29, 2022) captured that BA-8 would be very helpful in the program management, financial management, and cost estimating aspects of their program and would result in more optimal use of their personnel to be able to deliver more capability to the customer.

G. RECOMMENDATIONS

Based on the results of the analysis and the data provided by both teams, the researchers provide recommendations for increased effectiveness of the pilot program in this section. This includes recommendations on additional metrics that may be collected for further analysis of the program, recommendations on certain attributes of software acquisitions program that could further improve implementation of the pilot, and insight into how to deal with some of the challenges that the teams faced whilst using BA-8 funding.

1. Additional Metrics

The CEA conducted on the alternatives of traditional and BA-8 funding shows a slight increase in effectiveness based on the objectives of cadence and man-hours. However, the lack of metrics on efficiency being collected throughout the BA-8 pilot program was a major factor that limited the scope of this research. The lack of data limited the available options for determining objectives, created great statistical uncertainty around any results of the research due to the small data set, and precluded any hard recommendations as to the effectiveness of the BA-8 pilot so far. The cadence data were limited to two software deliveries, giving the analysis a small sample of data for the more heavily weighted objective. A recommendation for improvement in future analysis would be to collect additional data points on cadence. However, it is understood that this is a limitation of the MTC2 program only having two deliveries on which to provide information. The man-hour data displayed information from both before and after the transition of the MTC2 program to BA-8, and NCSA supplemented this data. Additional data on man-hours from NCSA would have developed a more in-depth comparison; therefore, another recommendation would be to have programs using traditional funding procure data equivalent to the data being collected by the BA-8 programs to give a clear comparison of the effect that BA-8 has on program effectiveness. An additional recommendation regarding the man-hour data would be to collect additional qualitative information to ensure an accurate analysis of the benefits that BA-8 provides. Information on how the man-hours saved in the budget team after the implementation of BA-8 were being utilized to increase efficiency would provide more insight into the impact that BA-8 has on efficiency increases in MTC2 or any of the other pilot programs.

Insufficient data affected the available objectives that could be established in the efficiency calculation. Going back to the first step of the MOE calculation, the objective hierarchy, which depicts the relationship between tiers of objectives, should work its way down to objectives that are both relevant and measurable. The objectives that were set were not all-encompassing of the aspects that contribute to the overall effectiveness of a software acquisition program. However, because of the data available, the analysis focused on cadence and man-hours as measures of efficiency.

To further improve future analysis of the effectiveness of the BA-8 program, the recommendation is that additional metrics should be collected to develop more objectives and expand the scope of the analysis. The time between the identification of a need and delivery of that need (i.e., mean time to develop) would provide the means to further analyze the speed of delivery. Data collected on customer satisfaction with the software builds or updates would allow for analysis of if BA-8 influences whether the program is able to deliver a better product to the customer. This objective would also prove to be more highly weighted in the CEA. Related to this objective is the collection of metrics on how well the program software meets requirements upon delivery. This metric would allow the analysis to determine if the program is affected by BA-8 in the execution of their software to properly meet their requirements. Further insight would be generated by performance metrics that specifically measure the amount of work delivered in conjunction with scope of the work. Traditional measures like source lines of code (SLOC), combined with completed features, scope, and a customer-centric valuation of those features would enable a more robust analysis of value added. Man-hour data beyond the budget team would give a more comprehensive analysis of whether BA-8 funding has a significant impact on program efficiency or if the saved man-hours are not as significant as they seem. These kinds of metrics can be summarized by focusing on the aspects of schedule and performance, which are two of the three pillars that a PM must balance in the execution of their program. Any metrics that further prove that BA-8 has an impact on the way that the program develops better-performing software for the customer and delivers this capability more quickly after recognizing the need would benefit the analysis when assessing the effectiveness of the program, especially in the realm of software acquisitions.

2. Program Selection

Another recommendation is based on program choice in participation in the pilot program. Based on the data required to conduct a thorough analysis on improvements in efficiency, reduced cycle times, and increased performance, certain aspects of a program may be more ideal to conduct this sort of analysis. MTC2 provided the periodic reports for the pilot program that were issued to Congress. The criteria for program selection are summarized in the initial report to Congress that MTC2 provided as follows:

- Nominated programs had to be fully funded; this could not be a get-well opportunity.
- Nominated programs had to have a moderate to high degree of success, based on criteria developed for Section 873/874 agile Pilots. The criteria, modeled on those developed by the Software Engineering Institute (SEI) Federally Financed Research and Development Center (FFRDC), encompass issues such as mission, program and acquisition strategy, organizational culture for agile adoption, project and customer environment, system attributes and technology environment.
- The portfolio should include both weapons systems and Defense Business Systems, to provide an adequate sample set.
- Preference was given to programs already participating in the agile pilot programs, to further support piloting agile approaches and leverage investments already made in monitoring and analysis. (MTC2, personal communication, September 23, 2022)

These criteria encompass programs that are established, successful, and participating in the agile initiative and attempts to diversify the range of software types participating in the pilot. As this research has shown, the criterion for choosing pilot programs fails to include programs that are set up to provide information and data, both historically and continuously, to maximize the efficacy of assessment and analysis of increased efficiency that BA-8 may provide. The recommendation, therefore, is to adjust the selection criteria to also encompass other program attributes. First, the program should have a regular software delivery schedule with historical data on deliveries. Optimally, this would include multiple deliveries per year. The increased cadence in combination with historical data on the program's software acquisitions cadence would increase the effectiveness of the analysis into how BA-8 affects a key component of acquisitions: time. Second, the percentage of current funding that is RDT&E should not be close to all the funding provided to the program. By ensuring that funding of the program is a healthy mix of RDT&E, O&M, and procurement appropriations, the pilot program will maximize the impact that BA-8 would have on operations in that program. Finally, the program should be collecting and reporting end-user feedback on their software capabilities, timeliness of updates or increments, unfulfilled requirements (quantity and duration), and uncorrected or unresolved issues (also, quantity and duration). This information would allow for additional metrics on whether BA-8 has any effect on the product delivered to the user by comparing the user satisfaction from before and after the implementation of BA-8.

3. Recommendations for Challenges

The first challenge faced by the MTC2 team was due to the CR in their first year of implementing BA-8 funding (MTC2, personal communication, September 23, 2022). The additional work created by this challenge negated most of the timesaving benefits that BA-8 was targeting. The recommendation is that cognizance of this issue, particularly with the classification of a transition program as a "new-start," be considered upon future implementation of the pilot program in other program offices. Alternatively, including in regulation or reform amplifying guidance and policies to minimize the negative effects that a CR has both on the program office and to the pilot program data and results. Furthermore, until policy and reform have been updated to reflect best practices for the transition and execution under single appropriation, the OUSD(A&S) and OMB should provide transition assistance and guidance to programs shifting to BA-8 to mitigate the impact caused by the general unfamiliarity with the oddities and particulars of a single RDT&E appropriation while performing functions that are beyond what would traditionally be categorized as such.

Another challenge recognized by both the MTC2 and NCSA teams was the difficulties with contracting and using a single appropriation line item. Specifically, MTC2 (personal communication, September 23, 2022) found it more difficult and was required to provide far more explanation when using BA-8 appropriations, as many were unfamiliar with its use. NCSA (personal communication, September 29, 2022) echoed this notion, as they felt that BA-8's usefulness could not be accurately assessed without more information on how it will be utilized in contracting. Therefore, the recommendation is to provide amplifying guidance on the use of BA-8 to mitigate these challenges with contracting and implementation of the funding. Resolving this will not only help reduce the impact on the budget and program office, but it will enable a more accurate representation of the long-term time-based benefits of single appropriations.

H. RESULTS SUMMARY

The CEA results show that while there was a significant decrease in average cost when transitioning from traditional to BA-8 funding, the increase in effectiveness was minimal as measured by the MOE score. Additionally, this analysis recognizes some of the weaknesses in the ability to analyze the available data. Specifically, additional metrics could be collected to increase the accuracy of a CEA. Some additional qualitative information on efficiency gains in the program would provide more insight on the effect that the pilot has on each program. Furthermore, analysis could also benefit from programs that meet certain criteria to maximize the benefit of single appropriation. With these considerations, a follow-on CEA conducted with improved metrics and attributes could yield a more accurate analysis and possibly demonstrate greater effectiveness in the BA-8 pilot program.

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V. CONCLUSION

This research set out to conduct a cost-effectiveness analysis (CEA) on BA-8 versus traditional appropriation methods and glean further insight to the drivers of effectiveness in DoD software-intensive programs. Specifically, the analysis was used to identify if colorless money results in more efficient software acquisition. Additionally, using the results of the CEA, the researchers determined what other measures of effectiveness (MOE) would provide more insight into the performance of this pilot program and how colorless appropriations could benefit other software acquisition programs.

When comparing attributes of programs that are not easily quantified, a CEA is a powerful tool to assess the potential benefit of alternatives. This analysis utilized the currently available data in the Maritime Tactical Command and Control (MTC2) and Naval Cybersecurity Awareness (NCSA) programs, which included man-hour, cost, and cadence data, to construct an objective analysis and determine an overall MOE for both traditional and BA-8 funding methods. This MOE was then used to conduct a CEA for both funding profiles.

This CEA found that BA-8 funding only results in an increase in effectiveness based on the objectives, value functions, and weighting chosen at reduced cost. However, BA-8 funding result in a faster delivery cadence, rather it resulted in a cadence that more closely matched cadence targets. This analysis is limited in accuracy due to the limitations of the available data and the MTC2 program itself. Recommendations are reiterated in the next section regarding additional metrics that could provide more insight into the program and considerations for future implementation of the BA-8 pilot program. The BA-8 pilot program must consider ways to improve data collection and future analysis of this initiative.

A. CONSIDERATIONS FOR FUTURE BA-8 PROGRAMS

The main consideration in the efficacy of this analysis is that the pilot programs selected for BA-8 did not have sufficient delivery history under traditional appropriations prior to transitioning to the BA-8 pilot. To remove this source of error in analysis, future pilot selection should identify programs with well-established and measured delivery cadence. Alternatively, programs that are anticipated to be capable of a rapid delivery cadence (e.g., on a biannual or faster cycle) could be selected immediately for inclusion in the BA-8 pilot; however, for analysis, this delivery cadence would need to be observed for a longer period (e.g., several years), include performance functionality MOEs, and be coupled with comparable control programs under traditional appropriations. Without this contrast, it will be difficult to accurately determine the effects of BA-8 on delivery cadence.

Studies such as the Software Acquisition and Practices (SWAP) study have correctly identified that the United States is lagging its competitors in software innovation (DIB, 2019). To make up ground, the Defense acquisition workforce and Congress must be willing to take risks to energize software development. The first step toward accelerating software acquisitions is to select pilot programs that are well established and use their results to measure the effectiveness of the BA-8 funding authorization. The second step is for these pilot programs to diligently collect performance data on how single appropriations funding affects every aspect of their acquisition, including end-user satisfaction, contractor relationships, and ability to quickly meet warfighter needs. This wholistic look at BA-8 funded efforts in action will allow acquisition professionals and Congress the necessary insight in determining whether single appropriation funding improves software acquisitions.

Another consideration for the future selection of BA-8 pilot programs is matching the flexibility of single appropriations funding to programs that require great flexibility to quickly identify and meet operational needs. The lean six sigma process of Define, Measure, Analyze, Improve, Control (DMAIC) can be useful in this determination, particularly with the use of a value-stream management (VSM). Through VSM, a system's process is mapped and visualized with accompanying process- and lead-times. From there, each step or action is categorized as Customer Value-Add (CVA, an action that adds value to the end user), Business Non–Value Added (BNVA, an action that does not add value but is a necessary business function), or Non–Value Added (NVA, an action that is neither required nor adds value and is therefore waste) (George et al., 2004).

In this case, the "system" would be the software acquisition program, and the VSM would look at the execution process of the program office, and functions like budgeting would be function steps along that process. The Defense Innovation Board (DIB) SWAP study recommendation for single appropriation in software acquisitions aligns with this lean six sigma methodology in that transitioning between colors of money is a BNVA action. Then, if one considers a single appropriation an equivalent replacement for multiple appropriation, then the additional work being conducted with multiple appropriations (e.g., creating a budget exhibit for each color of money) would be considered NVA or wasteful functions that should be eliminated. The divergence between the lean six sigma method and the DIB SWAP recommendation is the impact on cadence. With a VSM, one cannot only identify BNVA and NVAs, but also identify whether those actions are slowing the cadence of the whole process. If a program is delivering on a slow enough cadence, or bottlenecked by other actions [e.g., Authority to Operate (ATO) validation, hardware delivery lead times, ship or platform availability for delivery or install, etc.], then single or multiple appropriations may have no impact on delivery cadence. Therefore, increasing cadence by transitioning to a single appropriation can only be demonstrated if the acquisition program is currently operating with a budget-constrained, time-based bottleneck.

A final consideration for BA-8 funding inclusion is for programs constrained, not in time, but in availability to execute. In established software-intensive programs that also have significant hardware and installation costs, these programs would likely not be considered for inclusion because of the higher percentage of procurement and operations and maintenance (O&M) expenses that these programs incur. There is a consideration that may improve the outcome for the end-user, and that is trade space for the program manager (PM). For example, the submarine combat system (PMS 401) is executed on a 2-year cadence for software increments and a 2-year cadence for hardware increments, offset by 1 year from software. However, that is just for the availability of the build to be delivered, not in the actual delivery. The delivery and installation are then coordinated across long-term submarine maintenance schedules. One of the major challenges is that deployment and maintenance availabilities do not strictly follow these schedules, thus creating significant uncertainty for the PM and ultimately a delay and backlog of installations. This is further complicated by the necessity to plan and budget, on an annual basis, for simultaneous development, delivery, and installation of incremental builds to platforms that may or may not be available to receive them. A single appropriation could allow increased flexibility to the PM, enabling a more agile program execution response to the dynamic operations cycles of the intended platform. Instead of being constrained by budget or the bureaucratic process of shifting appropriations, a PM empowered by a single appropriation could optimize the active execution of the program; trading marginal research, development, test, and evaluation (RDT&E) value to fill a backlog in procurement and installation, resolving a major deficit in warfighting capability.

B. FUTURE RESEARCH

Once the scope and depth of data on BA-8 funded pilots are expanded, future researchers will be needed to analyze these data, determine appropriate objectives, and conduct a more comprehensive effectiveness analysis on BA-8. This work will be crucial for deciding if BA-8 should be expanded further for all software programs.

Additionally, future researchers should consider how to best match single appropriations to programs that need this flexibility the most. After analyzing and quantifying the benefits that the BA-8 funded program provides, future researchers may be able to apply these benefits to other software programs within the DoD and measure the potential effects on that program.

A major policy issue around BA-8 funding that can be researched is how to ensure accountability for these funds while also maintaining flexibility. If BA-8 funding is expanded to more software acquisitions programs, the DoD and Congress must work together to build a framework for accountability of this effort. Researchers could explore policy options to achieve this end and provide more clarity on the use of this appropriation category across the DoD.

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