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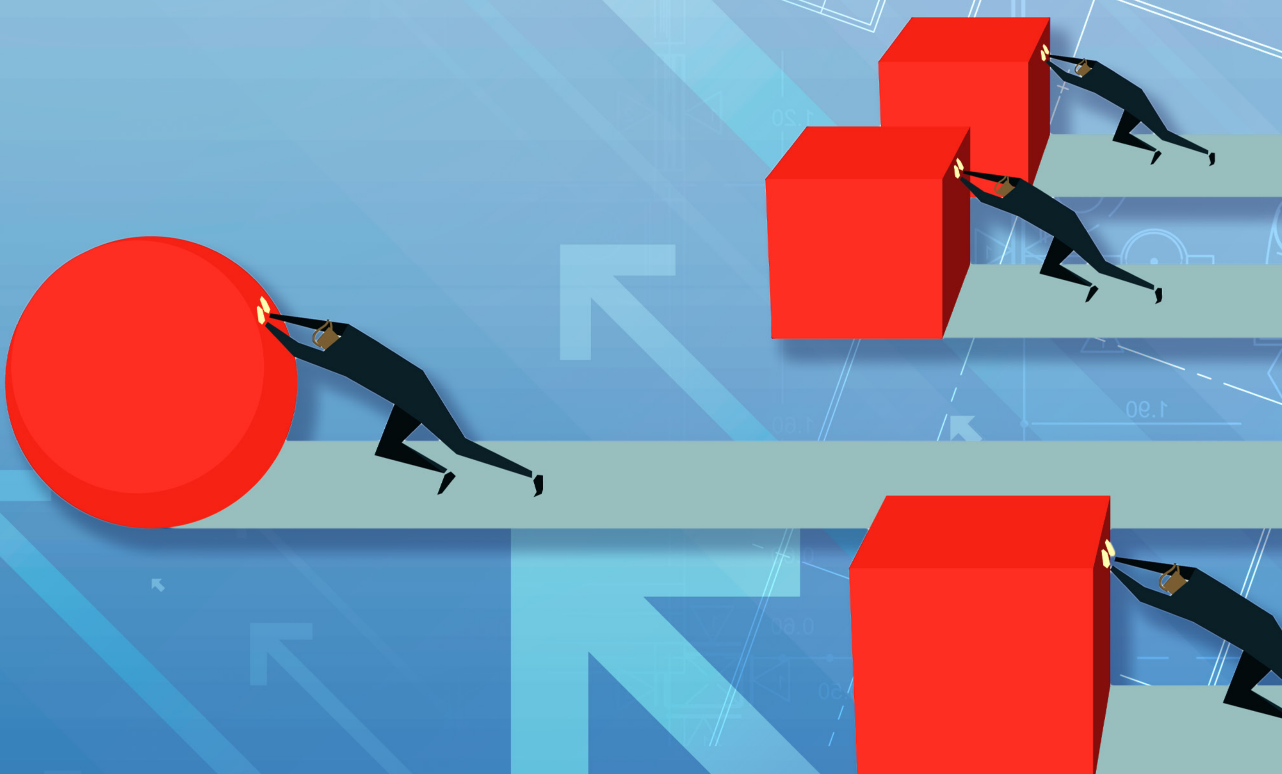

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Cost Estimation Trends for Major Defense Acquisition Programs

Capt Sammantha J. Jones, USAF, Edward D. White, Jonathan D. Ritschel, and Shawn M. Valentine

Successful Adoption of DevOps Practices in Software Development in DoD Acquisition Programs—The CREATE Example

Richard P. Kendall, Nathan S. Hariharan, David R. Sears, and Douglass E. Post

A Tale of Two Organizations: A Qualitative Comparative Study of Contracting Organizations

Jennifer W. Elkins

ARTICLE LIST

ARJ EXTRA

The Defense Acquisition Professional Reading List

Logistics: Principles and Applications (Second Edition)
Written by John W. Langford and reviewed by Shawn Harrison

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A Tale of Two Organizations: A Qualitative Comparative Study of Contracting Organizations

Jennifer W. Elkins

This research study investigates and compares the bureaucratic behaviors present within contracting organizations to understand better what characteristics of bureaucracy are exhibited within the two types of DoD acquisition organizations: technology enabling and traditional.

CONTENTS | Featured Research

FROM THE CHAIRMAN AND EXECUTIVE EDITOR

Dr. Larrie D. Ferreiro

The theme for this issue is "Improving the Process." The DoD has a long history of evolving its acquisition processes to become more efficient, more effective, and more responsive. The articles in this edition describe several efforts to analyze the impacts of some of those efforts.

The first article, by Capt Sammantha J. Jones, USAF, Edward D. White, Jonathan D. Ritschel, and Shawn M. Valentine, is titled "Cost Estimation Trends for Major Defense Acquisition Programs." The authors investigated how schedule and cost estimates compare across the 1970s to the 2010s for ACAT I programs. Their results indicate that program schedule slippage and cost growth have remained consistent over that 50-year period, but the variability of cost estimates has decreased over time, bringing somewhat more predictability to the process.

The second article is "Successful Adoption of DevOps Practices in Software Development in DoD Acquisition Programs—The CREATE Example" by Richard P. Kendall, Nathan S. Hariharan, David R. Sears, and Douglass E. Post. This case history describes how some of the widely acknowledged obstacles within DoD Acquisition programs were overcome using the DoD's Computational Research and Engineering Acquisition Tools and Environments (CREATE) portfolio suite to develop software pipelines, based on the principles of DevSecOps (development, security, and operations), a process that develops more consistent, relevant value to DoD acquisition customers across the Services.

The third article is by Jennifer W. Elkins, with the somewhat Dickensian title, "A Tale of Two Organizations: A Qualitative Comparative Study of Contracting Organizations." The author used interviews and behavioral analyses to compare and contrast one organization that exercises the new authorities provided in the DoD's adaptive acquisition framework (which came into effect in 2020), with another organization that operates in a traditional acquisition environment.

This issue's Current Research Resources in Defense Acquisition focuses on artificial intelligence (AI), which has seen a great increase in public awareness since the release of several generative AI platforms in late 2022 and early 2023.

The featured work in the Defense Acquisition Reading List book review is *Logistics: Principles and Applications* (Second Edition) by John W. Langford, reviewed by Shawn Harrison.

Mr. Eric Lofgren and Dr. Keith Snider have left the Editorial Board. We thank them for their service.

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Research Agenda 2023

This Research Agenda is intended to make researchers aware of the topics that are, or should be, of particular concern to the broad defense acquisition community in the government, academic, and industrial sectors. It is compiled using inputs from subject matter experts (SMEs) across those sectors. These topics are periodically vetted and updated as needed to ensure they address current areas of strategic interest.

The purpose of conducting research in these areas is to provide solid, empirically based findings to create a broad body of knowledge that can inform the development of policies, procedures, and processes in defense acquisition, and to help shape the thought leadership for the acquisition community. These research topics should be considered guidelines to help investigators form their own research questions. Some questions may cross topics and thus appear in multiple research areas.

Potential researchers are encouraged to contact the DAU Director of Research (research@dau.edu) to suggest additional research questions and topics, or with any questions on the topics.

Affordability and Cost Growth

- Define or bound "affordability" in the defense portfolio. What is it? How will we know if something is affordable or unaffordable?
- What means are there (or can be developed) to measure, manage, and control "affordability" at the program office level? At the industry level? How do we determine their effectiveness?
- What means are there (or can be developed) to measure, manage, and control "Should Cost" estimates at the Service, component, program executive, program office, and industry levels? How do we determine their effectiveness?
- What means are there (or can be developed) to evaluate and compare incentives for achieving "Should Cost" at the Service, component, program executive, program office, and industry levels?

- Recent acquisition studies have noted the vast number of programs and projects that don't make it through the acquisition system and are subsequently canceled. What would systematic root cause analyses reveal about the underlying reasons, whether and how these cancellations are detrimental, and how acquisition leaders might rectify problems?
- Do joint programs—at the inter-Service and international levels—result in cost growth or cost savings compared with single-Service (or single-nation) acquisition? What are the specific mechanisms for cost savings or growth at each stage of acquisition? Do the data lend support to "jointness" across the board, or only at specific stages of a program (e.g., only at research and development [R&D]), or only with specific aspects, such as critical systems or logistics?
- Can we compare systems with significantly increased capability developed in the commercial market to Department of Defense (DoD)-developed systems of similar characteristics?
- Is there a misalignment between industry and government priorities that causes the cost of such systems to grow significantly faster than inflation? If so, can we identify why this misalignment arises? What relationship (if any) does it have to industry's required focus on shareholder value and/or profit, versus the government's charter to deliver specific capabilities for the least total ownership costs?

Industrial Productivity and Innovation

Industry insight and oversight

- What means are there (or can be developed) to measure the level of oversight and/or control that government has over subcontractors?
- What means are there (or can be developed) to measure costs of enforcement (e.g., auditors) versus actual savings from enforcement?
- What means are there (or can be developed) to evaluate and compare incentives for subcontractor/supply chain competition and efficiencies?
- What means are there (or can be developed) to evaluate and compare market-based incentives with regulatory incentives?
- How can we perform institutional analyses of the behaviors of acquisition organizations that incentivize productivity?
- What means are there (or can be developed) to evaluate and compare the barriers of entry for SMEs in defense acquisition versus other industrial sectors?
- Is there a way to measure how and where market incentives are more effective than regulation, and vice versa?
- Do we have (or can we develop) methods to measure the effect of government requirements on increased overhead costs, at both government and industrial levels?
- Examine the possibilities to rationalize and balance the portfolio of capabilities through buying larger quantities of common systems/subsystems/components across Defense Agencies and Services. Are there examples from commercial procurement and international defense acquisition that have produced positive outcomes?

- Can principal-agent theory be used to analyze defense procurement realities? How?
- What means are there (or can be developed) to measure the effect on defense acquisition costs of maintaining the industrial base in various sectors?
- What means are there (or can be developed) of measuring the effect of utilizing defense industrial infrastructure for commercial manufacture, particularly in growth industries? In other words, can we measure the effect of using defense manufacturing to expand the buyer base?
- What means are there (or can be developed) to measure the breadth and depth of the industrial base in various sectors that go beyond a simple head count of providers?
- Has change in the industrial base resulted in actual change in output? How is that measured?

Independent research and development

- What means do we require to measure the cost-effectiveness or return on investment (ROI) for DoD-reimbursed independent research and development (IR&D)?
- Can we properly account for sales and revenues that are products of IR&D?
- Can we properly account for the barriers to entry for SMEs in terms of IR&D?
- Examine industry trends in IR&D, such as percentage of revenue devoted to IR&D and collaboration with academia. How do they vary by industry sector—in particular, those associated with defense acquisition?
- What means are there (or can be developed) to measure the ROI for DoD-reimbursed IR&D versus directly funded defense R&D?
- What incentive structures will motivate industry to focus on and fund disruptive technologies?
- What impact has IR&D had on the development of disruptive technologies?

Competition

Measuring the effects of competition

- What means are there (or can be developed) to measure the effect on defense acquisition costs of maintaining an industrial base in various sectors?
- What means are there (or can be developed) for measuring the effect of utilizing defense industrial infrastructure for commercial manufacture, particularly in growth industries? In other words, can we measure the effect of using defense manufacturing to expand the buyer base?
- What means are there (or can be developed) to determine the degree of openness that exists in competitive awards?
- What are the different effects of the two, best value, source selection processes (trade-off versus lowest price technically acceptable) on program cost, schedule, and performance?

Strategic competition

- Is there evidence that competition between system portfolios is an effective means of controlling price and costs?
- Does lack of competition automatically mean higher prices? For example, can sole source reduce overall administrative costs at both the government and industry levels, thereby lowering total costs?

- Describe the long-term historical trends for competition guidance and practice in defense acquisition policies and practices.
- To what extent are contracts awarded noncompetitively by congressional mandate for policy interest reasons? What is the effect on contract price and performance?
- What means exist (or can be developed) to determine the degree to which competitive program costs are negatively affected by laws and regulations such as the Berry Amendment, Buy American Act, etc.?
- The DoD should have enormous buying power and the ability to influence supplier prices. Is this the case? Examine the potential change in cost performance due to greater centralization of buying organizations or strategies.

Effects of industrial base

- What are the effects on program cost, schedule, and performance of having more or fewer competitors? What measures are there to determine these effects?
- What means are there (or can be developed) to measure the breadth and depth of the industrial base in various sectors, that go beyond a simple head count of providers?
- Has the change in industrial base changed the output? How is that measured?

Competitive contracting

- Commercial industry often cultivates long-term, exclusive (noncompetitive) supply chain relationships. Does this model have any application to defense acquisition? Under what conditions/circumstances?
- What is the effect on program cost performance of awards based on varying levels of competition: (a) “Effective Competition” (two or more offers); (b) “Ineffective Competition” (only one offer received in response to competitive solicitation); (c) “Split Awards” versus winner take all; and (d) “Sole Source.”

Improve DoD outreach for technology and products from global markets

- How have militaries in the past benefitted from global technology development?
- How/why have militaries missed the largest technological advances?
- What are the key areas that require DoD focus and attention in the coming years to maintain or enhance the technological advantage of its weapons systems and equipment?
- What types of efforts should DoD consider pursuing to increase the breadth and depth of technology push efforts in DoD acquisition programs?
- How effectively are DoD’s global science and technology (S&T) investments transitioned into DoD acquisition programs?
- Are managers of DoD’s applied R&D (i.e., acquisition program) investments effectively pursuing and using sources of global technology to affordably meet current and future DoD acquisition program requirements? If not, what steps could DoD take to improve its performance in these two areas?
- What are the strengths and weaknesses of DoD’s global defense technology investment approach as compared to the approaches used by other nations?

- What are the strengths and weaknesses of DoD's global defense technology investment approach as compared to the approaches used by the private sector—both domestic and foreign entities (companies, universities, private-public partnerships, think tanks, etc.)?
- How does DoD currently assess the relative benefits and risks associated with global versus U.S. sourcing of key technologies used in DoD acquisition programs? How could DoD improve its policies and procedures in this area to enhance the benefits of global technology sourcing while minimizing potential risks?
- How could current DoD/U.S. Government Technology Security and Foreign Disclosure (TSFD) decision-making policies and processes be improved to help DoD better balance the benefits and risks associated with potential global sourcing of key technologies used in current and future DoD acquisition programs?
- How do DoD primes and key subcontractors currently assess the relative benefits and risks associated with global versus U.S. sourcing of key technologies used in DoD acquisition programs? How could they improve their contractor policies and procedures in this area to enhance the benefits of global technology sourcing while minimizing potential risks?
- How could current U.S. Government Export Control system decision-making policies and processes be improved to help DoD better balance the benefits and risks associated with potential global sourcing of key technologies used in current and future DoD acquisition programs?

Comparative studies

- Compare the industrial policies of military acquisition in different nations and the policy impacts on acquisition outcomes.
- Compare the cost and contract performance of highly regulated public utilities with nonregulated "natural monopolies" (e.g., military satellites, warship building).
- Compare contracting/competition practices of DoD with the commercial sector in regard to complex, custom-built products (e.g., offshore oil platforms).
- Compare program cost performance in various market sectors: highly competitive (multiple offerors), limited (two of three offerors), or monopoly?
- Compare the cost and contract performance of military acquisition programs in nations having single "purple" acquisition organizations with those having Service-level acquisition agencies.

Cybersecurity

General questions

- How can we perform analyses of the investment savings associated with implementation of robust cybersecurity measures?
- How can we measure the cybersecurity benefits associated with using continuous integration and continuous deployment methodologies?
- How can we cost the discrete elements of cybersecurity that ensure operational effectiveness within the categories of system functions, mission execution, system performance, and system resilience?
- How can we assess the most effective methodologies for identifying threats quickly, assessing system risk, and developing countermeasures?

- How can we establish a repeatable process for incorporating a continuous Authorization to Operate construct for all software-centric acquisition programs?
- How can we articulate cyber risk versus operational risk so combatant commands can be better informed when accepting new software?

Costs associated with cybersecurity

- What are the cost implications of (adding) cybersecurity to a program?
- What are reasonable benchmarks for cybersecurity cost as a percentage of Prime Mission Product (PMP)?
- What are the key cost drivers associated with cybersecurity?
- Is cybersecurity best estimated as a below-the-line common element (similar to Systems Engineering/Program Management or Training) or a PMP element?
- How are risks associated with not incorporating cybersecurity appropriately best quantified/monetized?

Acquisition of Services

Metrics

- What metrics are currently collected and available on services acquisition within the DoD? Within the U.S. Government? Outside of the U.S. Government?
- What and how much do these metrics tell us about services acquisition in general and about the specific programs for which the metrics are collected?
- What are the possible metrics that could be used in evaluating services acquisition programs? How many metrics should be used? What is the efficacy of each metric? What is the predictive power of each metric? What is the interdependence (overlap) between metrics?
- How do we collect data for services acquisition metrics? What is being done with the data currently being collected? Are the data being collected on services acquisition reliable? Is the collection process affecting the data collected for services acquisition?
- How do we measure the impact of different government requirements on overhead costs and rates on service contracts?

Industrial base

- What is the right amount of contracted services for government organizations? What are the parameters that affect Make/Buy decisions in government services? How do the different parameters interact and affect government force management and industry research availability?
- What are the advantages, disadvantages, and impacts of capping pass-through costs, and how do they change with the value of those costs?
- Do Base Operations and Support (BOS) contracts have a best size? Should large BOS contracts be broken up? What are the parameters that should be considered?

- In the management of large service contracts, what is the best organization? Is the System Program Office a good model? What parameters should be used in evaluating the advantages and disadvantages of an organization to manage large service contracts?
- What effect does strategic sourcing and category management have on small business if the small business is a strategic source or is not a strategic source?
- Do the on-ramping and off-ramping requirements of some service contracts have an effect on the industrial base? If so, what are the impacts?

Industry practices

- What private sector business practices, other than maximizing profit, can the government effectively use to incentivize performance and otherwise improve business relationships with vendors?
- What are the best methods for evaluating different incentives to encourage small businesses to participate in government services contracts?
- What potential benefits can the government achieve from long-term supply chain relationships? What are the disadvantages?
- What benefits does industry get from the use of category managers and functional domain experts, and can the government achieve the same benefits?
- How can the government best capture, validate, and use demand management strategies?
- Are current services acquisition taxonomies comprehensive, or can they be improved?

Make/Buy

- What methods can best be used to define the cost-value relationship in different classes of service contracts?
- Can we develop a method for determining the "should cost" of different services?
- Can we define and bound affordability of specific services?
- What are the characteristics of "inherently governmental" activities, and how can we evaluate the value of these services based on comparable characteristics in a competitive labor market?
- In service contracts, what are the inherent life-cycle costs, and how do we capture the life-cycle costs in Make/Buy decision making?
- In the case of government services contracting, what are the factors that contribute to less-than-optimum Make/Buy decision making?

Category management/strategic sourcing

- What effect does strategic sourcing/category management have on competition (effects on short term versus long term; effects on competition outside of the strategic sourcing/category management area of consideration)?
- What metrics do different industries use for measuring the effectiveness of their supply chain management?
- Would the centralization of services acquisition contracts have measurable impacts on cost performance? Why or why not?

- What are the fundamental differences between the service taxonomy and the category management taxonomy, and are there means and good reasons to align the two taxonomies?

Contract management/efficacy

- What are the best ways to address the service parts of contracts that include both services and products (goods)?
- In the management of service contracts, what are the non-value-added tasks, and are there realistic ways to reduce the impact of these tasks on our process?
- When funds for services are provided via pass-throughs (i.e., from another organization), how are the requirements tracked, validated, and reviewed?
- Do undefinitized contract actions have an effect on contractor pricing and willingness, or lack of willingness to provide support during proposal analysis?
- For multiaward, Indefinite-Delivery, Indefinite-Quantity (IDIQ)-type contracts, is there a method for optimizing the different characteristics (number of vendors, timelines, on-ramping, off-ramping, etc.)?

Policy

- What current government policies inhibit alignment of contractors' approaches with the government's service acquisition programs?

Administrative Processes

- What means are there (or can be developed) to measure the efficiency and effectiveness of DoD oversight, at the Component, Service, and Office of the Secretary of Defense levels?
- What measures are there (or can be developed) to evaluate and compare the costs of oversight versus the cost savings from improved processes?
- What means are there (or can be developed) to empirically establish oversight process metrics as a basis for comparison? Can these be used to establish the relationship of oversight to cost/schedule/performance outcomes?
- What means are there (or can be developed) to study the organizational and governance frameworks, resulting in successful change management?
- To what extent (investment and performance) can scenario/simulation-testing improve the delivery of complex projects?
- Is there a comparative statistical divergence between organizational honesty (reality) and contractual relationships (intent) in tendering?
- How does one formulate relational contracting frameworks to better account for and manage risk and liability in a collaborative environment?

Human Capital of Acquisition Workforce

- What means are there (or can be developed) to measure ROI for acquisition workforce training?
- What elements of the Professional Military Education framework can be applied to improve the professionalism of the civilian Defense Acquisition Workforce?

- What factors contribute to the management and successful delivery of modern complex project management, including performance over the project life cycle?
- What behavioral leadership characteristics can be commonly observed in successful complex projects, contrasted against unsuccessful complex projects?
- What is the functional role of talent management in building organizational sustainability, performance, and leadership?
- How do we create incentives in the acquisition workforce (management, career, social, organizational) that provide real cost reductions?

Defense Business Systems

Organizational structure and culture in support of Agile software development methodologies

- At the beginning of the Business Capability Acquisition Cycle (BCAC) process, various steps are used to ensure accurate requirements are thoroughly documented and supported throughout the software development life cycle. How can these documentation requirements and processes be streamlined to support more direct-line communication between the end-user and software engineers? What are the hurdles to implementing these changes and how are they overcome? What are the effects of these changes on the organization or agency?
- Regarding new starts, how can the BCAC be modified specifically to support Agile development? How are these changes advantageous or disadvantageous to the customer and organization? Would these changes be helpful or detrimental to R&D versus a concurrent design and engineering software project?
- Generally, readiness review briefings within the BCAC are used to determine whether a project is at an acceptable state to go to the next step in the process. If software is developed and released to production within a single sprint (potentially every 2 weeks), how are test readiness reviews, systems requirements reviews, and production readiness reviews handled? How have the changes to these events made them more or less relevant?
- How are organizations and agencies structured to support concurrent software design and development? What organizational structure would support R&D and non-R&D information technology (IT) capabilities?
- What steps are used to choose Agile as the default software development process versus any other software development methodology (e.g., Waterfall, Spiral, or Incremental) for your organization? What are the effects on project cost, schedule, and performance?
- Within DoD agencies and military branches, has the adoption of Agile resulted in faster deployment of new IT capabilities to the customer? How is this determined and measured?
- Industry often produces software using Agile. The DoD's BCAC process can produce an abundance of bureaucracy counter to Agile principles. How does hiring a contractor to implement or maintain IT capabilities and introducing Agile software development methods within a BCAC non-Agile process create conflict? How are these conflicts resolved or reconciled?
- How is IT engineering investment and innovation supported throughout DoD? What organizational or cultural aspects of an agency are specific to that support?

Defense Acquisition and Society

- To what extent should the DoD use the defense acquisition process to effectuate various social policies? The existing procurement regime favors a dizzying array of private interests ranging from organized labor; domestic manufacturers and firms located in areas of high unemployment; small businesses, including disadvantaged and women-owned firms; blind, severely handicapped, and prison industries; and, most recently, environmentally friendly vendors. Affirmatively steering the government's business from the open marketplace to preferred providers adds complexity, thus increasing transaction costs throughout the procurement process, which absorbs scarce resources. (Source: IBM Center for the Business of Government, http://www.businessofgovernment.org)
- How significant are the transaction costs resulting from the administration's commitment to transparency (generally, and specifically in the context of stimulus or recovery spending)? In a representative democracy, transparency is critical. But transparency is expensive and time-consuming, and the additional resources required to comply with the recently enhanced disclosure standards remain an unfunded mandate. Thus, the existing acquisition workforce must devote scarce resources to an (admittedly legitimate) end other than the pursuit of value for money or customer satisfaction. Is there an optimal balance or a point of diminishing returns? In other words, at what point does the cost of developing transparent systems and measures exceed the benefits of that transparency? (Source: IBM Center for the Business of Government, http://www.businessofgovernment.org)

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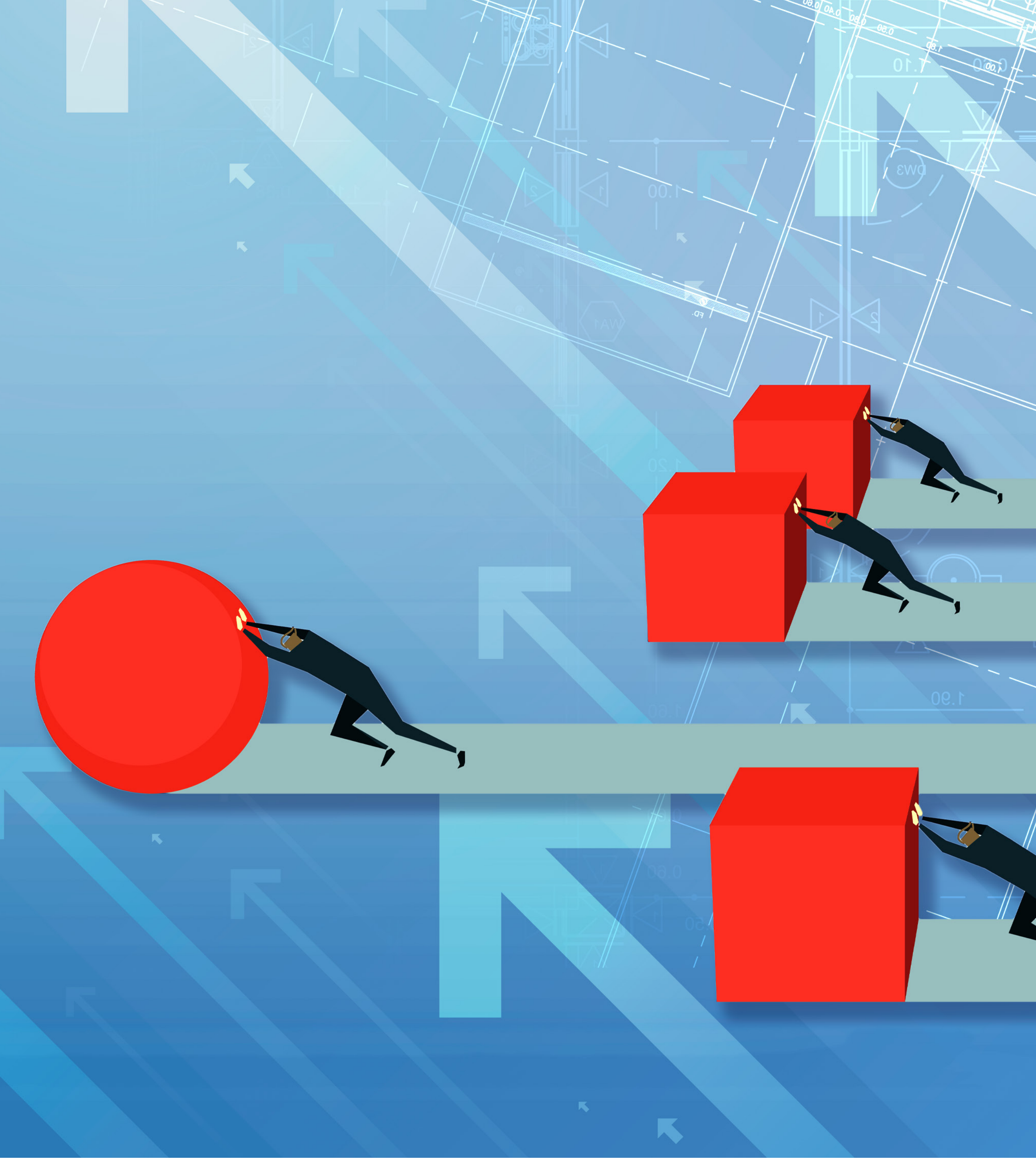

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Image designed by Ken Salter

COST ESTIMATION TRENDS

FOR MAJOR DEFENSE ACQUISITION PROGRAMS

Capt Sammantha J. Jones, USAF, Edward D. White, Jonathan D. Ritschel, and Shawn M. Valentine

The authors use both descriptive and inferential techniques to investigate average and standard deviation trends in cost estimates for major defense acquisition programs (MDAPs) grouped into decades from the 1970s to 2010s. For total program-cost-growth factors (CGFs), the 2010s exhibited lower CGFs compared to the 1990s. For the program-acquisition-unit cost (PAUC) CGFs, the 2010s appear lower than the 1990s and borderline lower than the 1970s. A statistically significant decreasing trend in the standard deviations of total program CGFs throughout the decades was identified. This lowering variability trend also appeared for PAUC CGFs from the 1980s onward. This finding appears to be the first documented case known to us. This decreasing variability of cost estimates suggests to us that cost estimating and/or the process behind it might be improving over time.

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Keywords: *Deviation trends, ACAT I, cost, variability, program estimates*

This article identifies macro-level trends of cost growth documented in DoD's selected acquisition reports (SARs) for major defense acquisition programs (MDAPs), grouped by decade from the 1970s to the 2010s. Specifically, we investigated overall program-cost growth and program-acquisition-unit cost (PAUC) growth for the DoD's largest program acquisitions. The inspiration for this study came from Arena et al. (2006) and Younossi et al. (2007). Both papers provide insights into cost growth of MDAPs that mainly originated prior to 2000. This article may be considered as an extension of these often-cited works with a key difference.

The difference is that we did not delineate between development and procurement costs; we consider these together as total program cost as reported in the SARs. Although separating cost growth into development and procurement is a common practice when analyzing MDAPs, we wanted to holistically look at the overall cost growth for this study. This article investigates cost growth from the 1970s to the 2010s and statistically assesses whether the DoD has seen a change of cost growth over this timespan regarding averages or standard deviations.

MDAPs are essential for the development and production of military aircraft, satellites, missiles, and other large investment items that U.S. military operations require.

Background

MDAPs are essential for the development and production of military aircraft, satellites, missiles, and other large investment items that U.S. military operations require. By statute, MDAPs are categorized as Acquisition Category (ACAT) I programs if they have either (a) total expenditure of research, development, test, and evaluation (RDT&E) costs greater than $525 million (fiscal year [FY] 2020 constant dollars); (b) total expenditure of procurement costs greater than $3.065 billion (FY 2020 constant dollars); or (c) are specifically designated by the milestone decision authority as special interest (DoD, 2020). MDAPs are the DoD's largest investments and constitute a large proportion of the DoD portfolio relative to their program numbers. These investments often entail large economic risks.

Currently, the Government Accountability Office (GAO) has reported consistent cost growth in the DoD's MDAP portfolio for the last 15 years and attributes the most dramatic cost changes to quantity changes (GAO, 2021). As referenced earlier, Arena et al. (2006) and Younossi et al. (2007) document historical precedent for underestimating program costs. Light et al. (2017) even recommended that the acquisition community approach early cost estimates with skepticism.

Cost growth in MDAPs appears commonplace; however, when programs experience dramatic growth, this can lead to what is known as a Nunn-McCurdy Breach (Defense Acquisition University [DAU], n.d.). From 1997 to 2016, 58 out of 189, or 36% of MDAPs experienced cost growth large enough to precipitate these breaches. Out of these 58 breaches, 18 were significant and 40 were critical (DoD, 2016, p. 65). Significant breaches occur when current cost estimates meet or exceed 15% of the current baseline estimate or 30% of the original baseline estimate of an acquisition program. Critical breaches occur at the 25% and 50% levels, respectively (DAU, n.d.).

MDAPs that experience Nunn-McCurdy breaches are extreme examples of cost growth. But due to MDAP programmatic costs, even small cost-growth percentages can add millions of additional funding needs for the programs. Because of these funding issues, efforts have continued over the last several decades to reduce cost growth within MDAPs (Fox et al., 2011). These efforts include sweeping reforms, changes in business practices, updates to recordkeeping requirements, and adjustments in the overall structure of how MDAPs are executed and their records maintained (Dwyer et al., 2020; Fox et al., 2011).

Over the last few decades, DoD has sponsored extensive studies and analyses on MDAPs. Various organizations such as the Congressional Research Service, the DoD itself, GAO, or even contracted organizations such as RAND or the Institute for Defense Analyses (IDA) conducted these studies. In 2016, the DoD published an annual acquisition system performance report. In this report, it analyzed MDAPs through a variety of different lenses, including cost and schedule growth, cost performance overall,

cost performance broken out by development and production, cost growth by military departments, cost growth by contractors, and a few other viewpoints (DoD, 2016).

The 2016 report claims that DoD analyses substantiate a continuing improvement in the field of defense acquisition; however, the Department's analyses concentrate on various microlevel insights into the cost growth of DoD MDAPs. While these microlevel assessments are important to understanding what is happening in specific MDAPs, DoD's study does not provide a macrolevel analysis that investigated whether overall cost growth of MDAPs has changed over several decades (DoD, 2016). That is the intent of this article.

Data and Methods

Data

We utilized only the Cost Assessment Data Enterprise (CADE) system to obtain the data for the analyses and information reported herein. Available since February of 2019, the CADE SAR database is a consolidation of DAMIR (Defense Acquisition Management Information Retrieval) SAR data and non-DAMIR legacy SARs. As of October 2021, we located 409 potential programs to analyze using the SAR Unit Cost Report along with the Current and Baseline Estimate report and the CADE SAR Data listing. Not all these programs contained data that fell within the bounds of our study. Table 1 highlights the reasons for program exclusion. For programs categorized as transitioned or restructured, if these actions led to the creation of a new MDAP, then that new program remained in the database. For example, the WIN-T, after being broken into three separate programs, drove the creation of only one MDAP that met the requirements for inclusion into our final dataset: the WIN-T increment 2. The other two no longer met the definition of an MDAP.

TABLE 1. SELECTED ACQUISITION REPORT (SAR) INCLUSION AND EXCLUSION CRITERIA

Total starting number of SARs available in CADE	*409*
Programs classified as terminated	*26*
Transitioned or restructured programs	*11*
SARs not classified as MDAPs [a]	*17*
SARs with no data available in CADE[b]	*25*
SARs with missing Milestone B data[c]	*129*
Ongoing programs < 5 years since Milestone B	*7*
FINAL MDAP SAR SAMPLE	**194**

Note. CADE = Cost Assessment Data Enterprise; MDAPs = Major Defense Acquisition Programs; SARs = Selected Acquisition Reports.

[a]This includes Pre-MDAP, Other, Special Interest, Major Automated Information System, Major System, and Department of Energy Program classifications.

[b]These programs were listed in CADE but had no cost data available for analysis.

[c]These programs did not have any Milestone B data available as a starting point for the cost growth analysis.

We use Milestone (MS) B as the starting point for collecting program data, as this is typically considered the official start of a program (DoD, 2020). Additionally, many previously published studies (Dwyer et al., 2020; McNicol, 2018; Younossi et al., 2007) have used Milestone B (MS B) as the starting point for their analyses on MDAP cost or schedule variations. As evident from Table 1, the largest exclusion factor was missing MS B data. Approximately 32% of the program exclusions resulted from the SARs not reporting any cost data at MS B.

The final exclusion criteria for our analysis involved accounting for the low maturity level of modern MDAPs. Ongoing programs that were less than 5 years old (and had yet to complete Initial Operating Capability) were omitted from the analysis. This is because of the increased likelihood of these less-than-mature programs not having yet realized their cost changes compared to programs further along in development/production. This maturity requirement led to the exclusion of seven MDAPs that reached MS B in 2017 or later. Younossi et al. (2007) adopted a similar exclusion criterion.

After the completion of this initial 194 MDAP database, we parsed the data into two separate databases to explore total program cost growth (RDT&E plus procurement costs) and PAUC growth individually. For investigating the Cost Growth Factor (CGF) (fuller definition to follow) for overall program total, a program was required to have cost data at MS B as well as on the last reported SAR. Eleven programs were missing cost data, reducing the initial 194 to 183 MDAPs for analyzing the CGF with respect to total program growth. For analyzing changes in PAUC, a program also needed quantity data. This 183 was further reduced to 165 since 18 MDAPs were missing quantity data. The Appendix to this article lists the MDAPs against which researchers compared these two databases' total program and PAUC growth over the decades.

We analyze the MDAP data by MS B plus 5 years (which we denote MS B + 5), completed, and ongoing. This MS B + 5 stems from Arena et al. (2006) as one way to account for maturity bias as well to amalgamate the completed and ongoing programs for overall analysis. Of the 183 MDAPs used for analyzing the total program CGF, 118 entailed completed programs with 65 still documented as ongoing in the SARs. For analyzing PAUC growth, these numbers were 102 and 63, respectively. We define completed as any MDAP that no longer reports any SAR information. Ongoing is just the opposite. Those ongoing MDAPs still report SAR data even for programs for which an MS B date was set, perhaps decades ago. We recognize a possible issue here with earlier units produced possibly differing from later production units. We address this unit limitation shortly.

After finalizing our two databases, we standardized all the cost data. Since these MDAPs can take many years to complete, instances arise where their costs are re-baselined to a different FY. Several program estimates at MS B were reset to an earlier FY, while the current estimates were in a different FY. To ensure internal consistency for a program, we used the current base years for each program and standardized all cost data to that particular year. We used the Secretary of the Air Force raw inflation indices to perform these calculations (U.S. Air Force, n.d.).

Responses

In our analyses, we compare how two responses have changed from the 1970s to the 2010s, with MS B start years grouped by decades. These two responses consist of changes in total program cost and PAUC. To analyze total program cost growth, we took the last reported total cost value associated with an MDAP and divided it by the estimated total program cost at MS B (or equivalent based on acquisition programs from earlier time periods). Equation 1 displays the calculation that generated CGFs for our analysis. A CGF of 1 equates to a program experiencing no change in total program cost from MS B to the latest SAR. A value less than 1.0 suggests the program costs are less than estimated at MS B, while a value greater than 1.0 shows an increase in total program growth. Other researchers used this

CGF calculation in previous cost-growth studies (Arena et al., 2006; Kozlak et al., 2017; Younossi et al., 2007). (Note: The MS B + 5 data last reported is changed to the SAR data at MS B + 5 years.)

Total Program Cost Last Reported / Total Program Cost Estimated at MS B (1)

The second response analyzed focused on the unit level, specifically at the PAUC. Quantity changes could drive some cost growth within MDAPs. To analyze the PAUC changes, we divided the total number of units estimated on the MS B SAR by the total cost estimate on the same SAR. (Note: The total number of units includes development and production units.) Then we calculated the current PAUC by taking the quantity reported on the latest SAR and dividing that by the latest program cost. Equations 2 and 3 highlight these calculations. After those two values were determined, we then divided (3) by (2) to arrive at the PAUC CGF.

Total # of Units Estimated at MS B / Cost Estimate Estimated at MS B (2)

Total # of Units Last Reported / Cost Estimate Last Reported (3)

It should be noted that along with issues and limitations brought forth and discussed by Hough (1992) regarding using SAR data, Davis et al. (2017) and Davis and Tate (2019) address the potential nonstandardization definition of a unit in the SAR affecting data analysis. In other words, detecting any trend of PAUC cost growth (or even lack thereof) might not be due to cost growth directly but rather an artifact from a changing definition of a procurement unit. Davis et al. (2017) and Davis and Tate (2019) describe the common differences among unit definitions as follows: changes over time, mixed types of units, and reporting accidents. As time increases from the first production unit to the last unit, the likelihood of what constitutes a unit increases as perhaps more capabilities are added from the initial unit for a particular MDAP. This is a limitation for which we need to be cognizant going forward.

Statistical Analysis

The goal for our analysis is to compare the decades, 1970s to 2010s, with respect to total program CGF and PAUC CGF. We conduct these analyses for MS B + 5, completed MDAPs, and then ongoing programs. These analyses consist of a combination of descriptive and inferential statistics. The descriptive statistics include reporting means, medians, standard deviations, coefficient of variations (CVs), and interquartile ranges (IQRs) by decade.

Regarding inferential analyses, the standard F-test conducted under an Analysis of Variance was originally thought to be the best methodology to compare responses across the decades. However, the non-normality pattern of the data indicated a nonparametric approach would be more appropriate given such inferential techniques have no distributional assumptions. Consequently, we utilized the nonparametric Kruskal-Wallis (K-W) test to determine statistically significant differences in the responses across the decades (Laerd Statistics, 2018). The specific null hypothesis tested is that the responses across the decades are equivalent versus the alternative hypothesis that at least one decade performs differently than the others.

If the null hypothesis is rejected, then we use the nonparametric Steel-Dwass (S-D) (Crichtlow & Fligner, 1991) pairwise comparison to isolate the specific different decade(s). Because the K-W test (and subsequent S-D test) needs at least five observations per group for statistical validity (Kruskal & Wallis, 1952), we excluded from inferential consideration any decade that did not meet the sample size criteria for either the total program CGF or PAUC CGF analysis. This exclusion was because of lack of statistical power for any specific inferential conclusion.

The K-W and S-D inferential nonparametric tests are concerned with the typical or average response of a variable of interest. To assess how the variability of our responses (total program CGF and PAUC CGF) might change across the decades, we employed the Brown-Forsythe (B-F) test. The B-F tests whether the response standard deviations/variances are equal or different across the decades. The B-F analyzes deviations based on the medians rather than the means of the data to minimize the effect of outliers or skewness in the data (Brown & Forsythe, 1974; Statistics How To, 2023). Since our data are not normally distributed, utilizing the B-F test provides more robust results versus the Levene Test, which uses means in its calculation. A level of significance of 0.05 was the default value that we used for all inferential hypothesis tests.

Analysis and Results

MS B + 5

We first start with analyzing total program CGF by decade for MDAPs at their MS B + 5-year point. This allows us to examine a large majority of our programs (completed and ongoing) against one another without the comparisons being distorted by maturity bias. As evident in Figure 1, we can quickly identify that each decade has outliers; however, it does appear as though the distance of the outliers from the individual decades' IQRs is decreasing over the course of the five decades analyzed.

The K-W and B-F tests returned p-values of 0.097 and 0.11, respectively. The p-value of 0.097, although not significant at the 0.05 level, does support evidence that the 2010s possessed lower total program CGFs (at the MS B + 5-year point) than the other decades if one was willing to increase the level of a Type I error to 0.10. The p-value of 0.11 might be misleading as Table 2 illustrates that both the mean and standard deviations have been decreasing over the decades and the B-F is a conservative test. This downward trend, although descriptive, appears to be a novel finding we have not seen in prior literature. From our perspective, we have read many studies that documented the patterns of cost growth, but none documented the actual variability of this process.

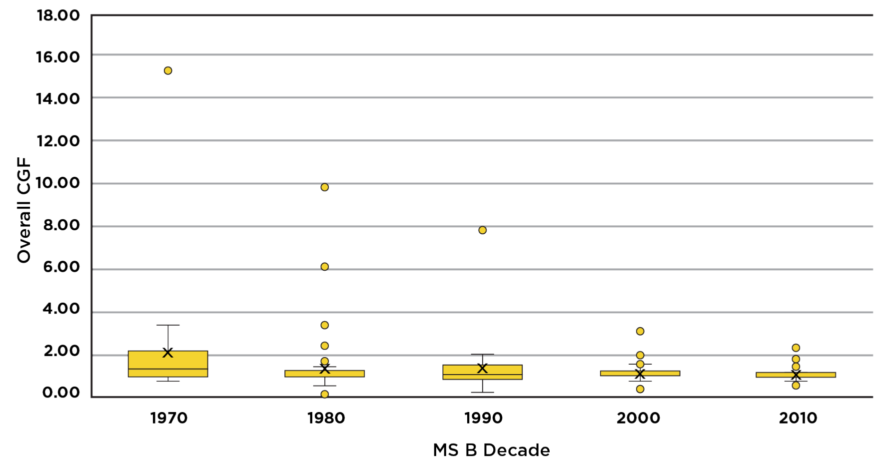
TABLE 2. OVERALL CGF SUMMARY STATISTICS—MS B + 5-YEAR MDAP DATA

MS B Decade	Observations	Mean	Median	Std Deviation	IQR	CV
1970	28	2.09	1.31	2.70	1.17	1.30
1980	37	1.44	1.01	1.74	0.28	1.21
1990	33	1.37	1.10	1.24	0.63	0.90
2000	42	1.16	1.10	0.45	0.25	0.38
2010	29	1.13	1.02	0.37	0.23	0.33

Note. CGF = Cost Growth Factor; CV = Coefficient of Variation; IQR = Interquartile Range; MDAP = Major Defense Acquisition Program; MS = Milestone; Std = Standard.

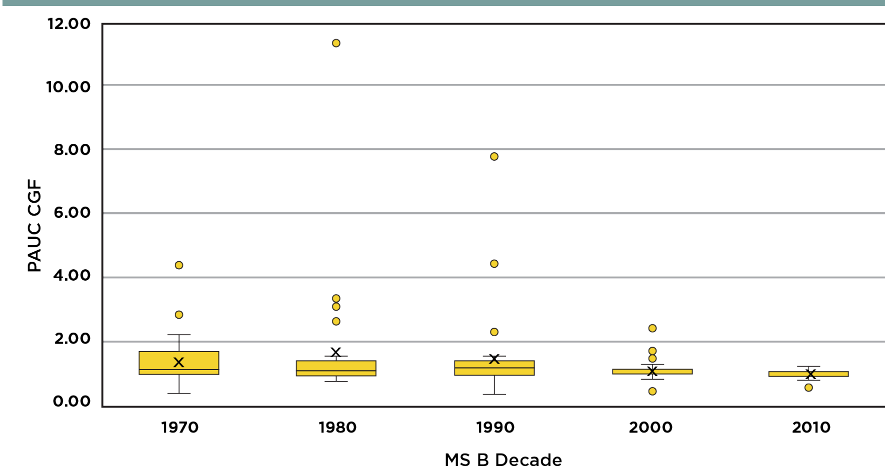
Looking at PAUC CGF by decade for MDAPs at their MS B + 5 year, Figure 2 shows the pattern and reveals that each decade appears to have outliers, with the 1980s and 1990s being the larger of the group. As with Figure 1, the width of the boxplot is decreasing, suggesting a decreasing IQR over the decades. Table 2 presents the summary statistics of the PAUC CGF MS B + 5 by decade and supports this shrinking IQR trend.

FIGURE 1. BOX PLOT—OVERALL TOTAL PROGRAM CGF AT MS B + 5-YEAR POINT



Note. CGF = Cost Growth Factor; MS = Milestone.

FIGURE 2. BOX PLOT—PAUC CGF AT MS B + 5-YEAR POINT



Note. CGF = Cost Growth Factor; MS = Milestone; PAUC = Program Acquisition Unit Cost.

The K-W and B-F inferential tests returned p-values of 0.084 and 0.088, respectively, for the data in Table 3. The K-W p-value of 0.084, although not significant at the 0.05 level, does suggest that there may be evidence that the 2010s possessed lower PAUC CGFs (at the MS B + 5-year point) than the other decades if one was willing to increase the level of a Type I error to 0.10. The p-value of 0.088 might be misleading, as Table 3 illustrates that the IQR

has been decreasing overall since the 1970s; both the mean and standard deviations also have been decreasing overall from the 1980s. Similar to the total program CGF at MS B +5 results, this decrease in standard deviation is the primary novel finding.

TABLE 3. PAUC CGF SUMMARY STATISTICS—MS B + 5-YEAR MDAP DATA

MS B Decade	Observations	Mean	Median	Std Deviation	IQR	CV
1970	*26*	*1.37*	*1.06*	*0.83*	*0.72*	*0.61*
1980	*31*	*1.66*	*1.10*	*1.93*	*0.47*	*1.16*
1990	*33*	*1.44*	*1.19*	*1.33*	*0.45*	*0.92*
2000	*38*	*1.08*	*1.07*	*0.30*	*0.14*	*0.27*
2010	*27*	*0.98*	*1.00*	*0.13*	*0.12*	*0.14*

Note. CGF = Cost Growth Factor; CV = Coefficient of Variation; IQR = Interquartile Range; MDAP = Major Defense Acquisition Program; MS = Milestone; PAUC = Program Acquisition Unit Cost; Std = Standard.

Completed

We now duplicate the prior analyses but restrict their inclusion to just-completed MDAPs. We also remove the MS B + 5 restriction used in the prior analysis. Thus, this section of analysis captures fully completed programs.

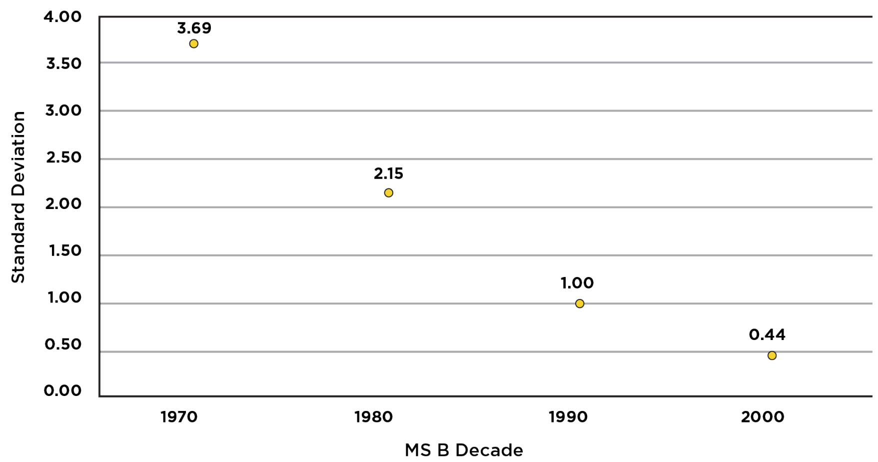
Table 4 presents the total program CGF by decade with the 2010s removed due to the sample size requirement of the K-W and S-D tests (as discussed earlier). The 2010 decade had only two completed MDAPs. The K-W and B-F hypothesis tests returned p-values of 0.13 and 0.03, respectively. The p-value of 0.13 suggests that the decades are similar with respect to total program CGF for completed MDAPs, but the 0.03 for the B-F suggests that the variability is not equal. As seen in Figure 3, a decreasing trend is evident in total program CGF variability by decade (sans 2010).

TABLE 4. OVERALL CGF SUMMARY STATISTICS—COMPLETED PROGRAMS

MS B Decade	Observations	Mean	Median	Std Deviation	IQR	CV
1970	*28*	*2.83*	*1.37*	*3.69*	*2.91*	*1.30*
1980	*41*	*1.50*	*0.98*	*2.15*	*1.31*	*1.43*
1990	*29*	*1.41*	*1.01*	*1.00*	*1.27*	*0.71*
2000	*18*	*1.14*	*1.11*	*0.44*	*0.25*	*0.39*

Note. CGF = Cost Growth Factor; CV = Coefficient of Variation; IQR = Interquartile Range; MS = Milestone; Std = Standard.

FIGURE 3. STANDARD DEVIATIONS—OVERALL CGF OF COMPLETED PROGRAMS



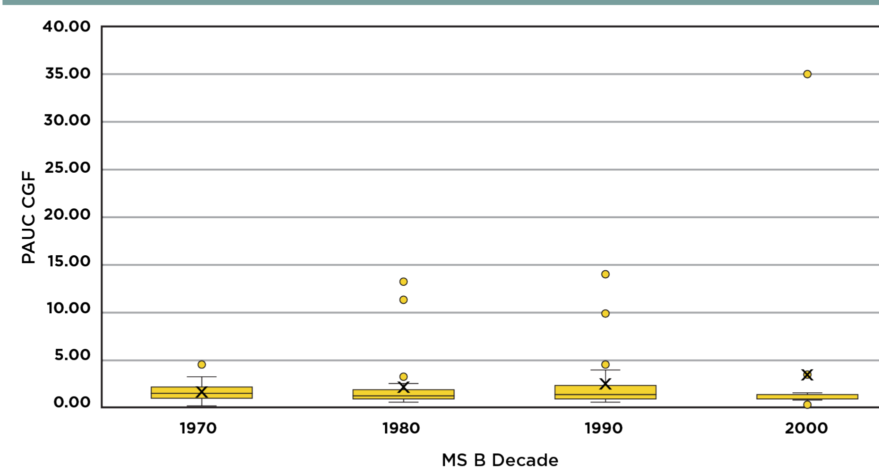
Note. CGF = Cost Growth Factor; MS = Milestone.

Table 5 presents summary statistics of the PAUC CGF by decade with, again, the 2010 decade (only two MDAPs) removed and the exclusion of the C-130 Aviation Modernization Program (AMP) MDAP from the 2000 decade (see Figure 4). The K-W and B-F tests (which did include the C-130 AMP) returned p-values of 0.49 and 0.53, respectively. These inferential results suggest no statistical differences with respect to the PAUC CGF (values or standard deviations) for the 1970s to the 2000s.

TABLE 5. PAUC CGF SUMMARY STATISTICS—COMPLETED PROGRAMS (EXCLUDING C-130 AMP FOR THE 2000 DECADE)						
MS B Decade	Observations	Mean	Median	Std Deviation	IQR	CV
1970	25	1.55	1.36	0.91	1.10	0.59
1980	31	2.03	1.05	2.83	0.90	1.40
1990	29	2.29	1.26	2.88	1.37	1.26
2000	14	1.19	1.07	0.66	0.19	0.56

Note. AMP = Aviation Modernization Program; CGF = Cost Growth Factor; CV = Coefficient of Variation; IQR = Interquartile Range; MS = Milestone; PAUC = Program Acquisition Unit Cost; Std = Standard.

FIGURE 4. BOX PLOT—PAUC CGF (INCLUDING C-130 AMP OUTLIER)



Note. AMP = Aviation Modernization Program; CGF = Cost Growth Factor; MDAPs = Major Defense Acquisition Programs; MS = Milestone; PAUC = Program Acquisition Unit Cost.

Ongoing

This section finishes our analysis by focusing on ongoing MDAPs only, again, without restricting the data at MS B + 5. The 2000s and 2010s contain the bulk of our ongoing programs, but programs also are included from the 1990s and earlier that are still active and ongoing (e.g., reporting development/production SARs). Because the K-W test needs at least five observations per group for statistical validity, we removed from inferential consideration any decade that did not meet the sample size criteria for either the total program CGF or PAUC CGF analysis. This provides a way to minimize the effects of very long programs.

Table 6 presents the total program CGF for ongoing MDAPs still reporting development/production SARs. The K-W and B-F returned p-values of 0.007

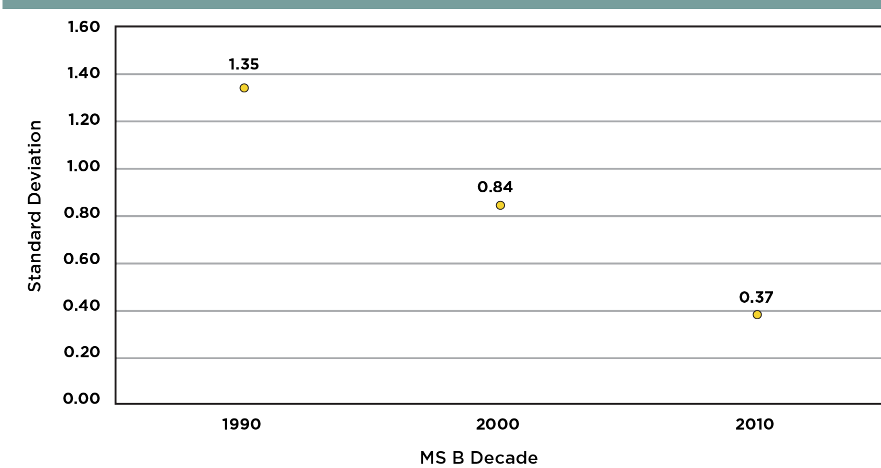
and 0.002, respectively. The p-value of 0.007 suggests that the decades are different with respect to total program CGF. The S-D test returned a p-value of 0.01 when comparing the 1990s and 2010s, indicating that the 1990s total program CGFs were statistically higher than those of the 2010s. The 2000s were statistically equivalent to both decades. The 0.002 p-value for the B-F test suggests that the standard deviations associated with total program CGF are not equal across the decades. As seen in Figure 5, a decreasing trend occurs in total program CGF variability by decade—a trend we witnessed in Figures 1 and 3.

TABLE 6. OVERALL CGF SUMMARY STATISTICS—ONGOING PROGRAMS

MS B Decade	Observations	Mean	Median	Std Deviation	IQR	CV
1990	*8*	*2.56*	*2.79*	*1.35*	*2.24*	*0.53*
2000	*24*	*1.47*	*1.21*	*0.84*	*0.64*	*0.57*
2010	*27*	*1.16*	*1.04*	*0.37*	*0.24*	*0.32*

Note. CGF = Cost Growth Factor; CV = Coefficient of Variation; IQR = Interquartile Range; MS = Milestone; Std = Standard.

FIGURE 5. STANDARD DEVIATIONS—OVERALL CGF OF ONGOING PROGRAMS



Note. CGF = Cost Growth Factor; MS = Milestone.

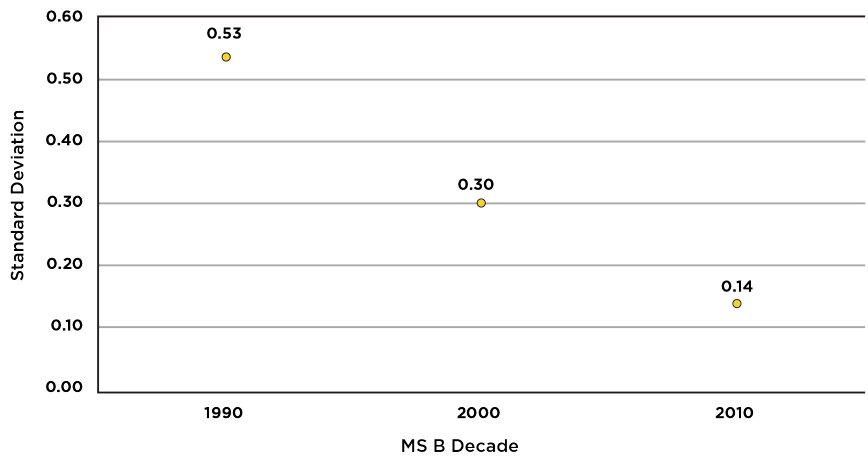
Table 7 presents summary statistics of the PAUC CGF by decade with an outlier (not necessarily an anomaly) in the 1990s—the National Security Space Launch (NSSL) MDAP—temporarily omitted. When including the NSSL, the 1990s' mean increases from 1.0 to 1.67, the standard deviation from 0.53 to 1.96, and the coefficient of variation from 0.54 to 1.18. The NSSL program possessed approximately a 6.0 PAUC CGF, while the next highest was around 1.6. We kept this MDAP for the inferential analysis since its presence (or omission) did not affect the statistical conclusions. The K-W and B-F tests returned p-values of 0.21 and 0.002, respectively. The p-value of 0.21 suggests PAUC CGFs through the three decades investigated are statistically equivalent. The p-value for the B-F test suggests that the variability associated with PAUC CGF is not equal. As seen in Figure 6 (using the smaller standard deviation without NSSL to preclude distorting the visual trend), a decreasing trend appears in PAUC CGF variability for the last three decades—a trend also shared by total program CGF. The next section discusses the significance of the statistical findings from our analysis.

TABLE 7. PAUC CGF SUMMARY STATISTICS—ONGOING PROGRAMS (EXCLUDING THE NSSL MDAP)

MS B Decade	Observations	Mean	Median	Std Deviation	IQR	CV
1990	7	1.00	1.21	0.53	0.91	0.54
2000	24	1.16	1.15	0.30	0.44	0.26
2010	27	1.01	1.02	0.14	0.19	0.14

Note. CGF = Cost Growth Factor; CV = Coefficient of Variation; IQR = Interquartile Range; MDAP = Major Defense Acquisition Program(s); MS = Milestone; NSSL = National Security Space Launch; PAUC = Program Acquisition Unit Cost; Std = Standard.

FIGURE 6. STANDARD DEVIATIONS—PAUC CGF OF ONGOING PROGRAMS



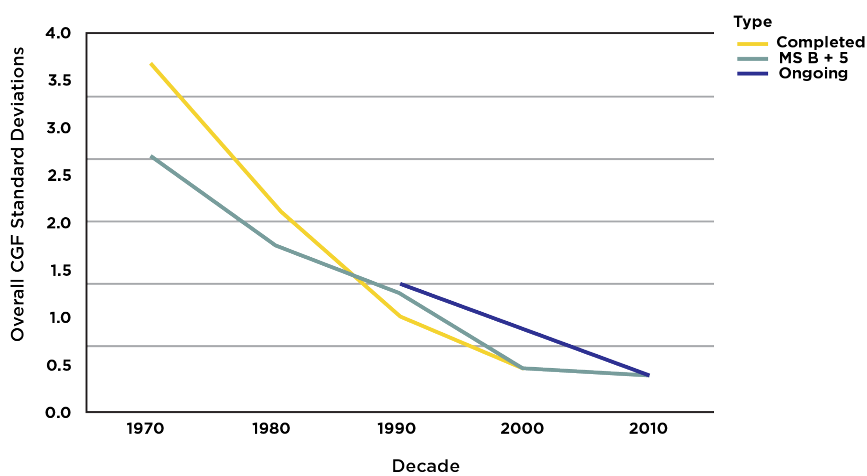
Note. CGF = Cost Growth Factor; MS = Milestone; PAUC = Program Acquisition Unit Cost.

Conclusions

Overall, the K-W nonparametric tests identified very few instances where the values themselves, either total program CGF or PAUC CGF, statistically differed across the decades. From a macro perspective, all were positive, meaning that overall, a typical MDAP likely will experience cost growth, and this growth has been consistent from the 1970s to the 2010s. Numerous studies have supported this finding and are well-documented in Arena et al. (2006) and Younassi et al. (2007), and references therein.

The main takeaway from the study's results lies within the standard deviations/variances of the CGFs across the decades. Differences in the variances for overall CGF and PAUC CGFs are noted for ongoing and completed programs as well when measured at the MS B + 5 point. The overall CGF variance decreased through the five decades reviewed, while the PAUC CGF increased in the 1980s and then subsequently decreased each decade after that. When analyzing completed programs, the overall CGF of MDAPs had statistical differences in the standard deviations, decreasing since the 1970s. The PAUC CGF of ongoing programs also displayed differences in variances across the three decades contained in the analysis with, again, a decrease in the standard deviation for each decade. Figure 7 best illustrates the patterns of these decreasing standard deviations.

FIGURE 7. STANDARD DEVIATIONS OF OVERALL TOTAL PROGRAM CGF'S



Note. CGF = Cost Growth Factor; MS = Milestone.

Although no identifiable statistical trends pointed to the DoD improving its cost estimation accuracy, the variances of the cost estimates have noticeably decreased from the 1980s onward. This appears to be a new finding that

The main takeaway from the study's results lies within the standard deviations/variances of the CGFs across the decades.

we have not previously seen in the literature. MDAPs are very expensive and time-consuming programs. These programs often push technology capabilities. That alone suggests that cost growth might just be endemic to MDAPs. However, the decreasing variability of cost estimates suggests to us that the process of cost estimating might be improving over time. This appears to be a good news story for the acquisition cost community in general.

APPENDIX: COMPLETE DATABASE BY RESPONSE OF INTEREST

Program	Service	Commodity	MS B Decade	MS B CGF	MS B PAUC CGF
A-10	*Air Force*	*Aircraft*	*1970*	*15.496*	*0.554*
ALCM (Air-Launched Cruise Missile)	*Air Force*	*Missile*	*1970*	*0.862*	*1.675*
B-52 OAS/CMI MODS	*Air Force*	*Aircraft*	*1970*	*0.965*	*0.972*
C/MH-53E	*Navy*	*Helicopter*	*1970*	*3.952*	*1.343*
CH-47D	*Army*	*Helicopter*	*1970*	*1.16*	*1.067*
DSCS (Defense Satellite Communications System) III	*DoD*	*Space*	*1970*	*1.585*	*1.585*
E-3A	*Air Force*	*Aircraft*	*1970*	*8.724*	*0.844*
EF-111A	*Air Force*	*Aircraft*	*1970*	*1.913*	*2.009*
F-15	*Air Force*	*Aircraft*	*1970*	*4.096*	*0.408*
F-16	*Air Force*	*Aircraft*	*1970*	*3.661*	*1.081*
GLCM (Ground Launched Cruise Missile)	*Air Force*	*Missile*	*1970*	*1.686*	*2.096*
Guided Projectile 8-Inch	*Navy*	*Ordnance*	*1970*	*0.059*	
Harpoon	*Navy*	*Missile*	*1970*	*5.69*	*4.471*
IUS	*Air Force*	*Space*	*1970*	*0.86*	*2.088*
LAMPS MKIII (SH-60B)	*Navy*	*Helicopter*	*1970*	*1.437*	*1.62*
Laser Hellfire	*Army*	*Missile*	*1970*	*1.893*	*0.245*
M1/M1A1 ABRAMS TANK	*Army*	*Vehicle*	*1970*	*3.72*	*3.356*
MAVERICK (IR)	*Air Force*	*Missile*	*1970*	*1.292*	*1.612*
MK 48 Torpedo	*Navy*	*Ordnance*	*1970*	*0.766*	*1.13*
Peacekeeper	*Air Force*	*Missile*	*1970*	*0.768*	*1.679*

APPENDIX: COMPLETE DATABASE BY RESPONSE OF INTEREST

Program	Service	Commodity	MS B Decade	MS B CGF	MS B PAUC CGF
Pershing II	*Army*	*Missile*	*1970*	*0.355*	
PHALANX CIWS (MK-15)	*Navy*	*Ordnance*	*1970*	*1.705*	*0.927*
PHOENIX (AIM-54C)	*Navy*	*Missile*	*1970*	*12.462*	*2.334*
PLSS (Precision Location Strike System)	*Air Force*	*Electronic/ Automated Software*	*1970*	*0.657*	
SFW (Sensor Fuzed Weapon)	*Air Force*	*Ordnance*	*1970*	*0.715*	*2.145*
SINCGARS	*Army*	*Electronic/ Automated Software*	*1970*	*0.696*	*0.912*
SPARROW (AIM-7M) (N)	*Navy*	*Missile*	*1970*	*1.076*	*1.355*
TOMAHAWK	*Navy*	*Missile*	*1970*	*2.723*	
TRIDENT Sub	*Navy*	*Ship*	*1970*	*0.999*	*1.239*
A-6E / A-6 Upgrade	*Navy*	*Aircraft*	*1980*	*2.201*	*0.528*
ACM (Advanced Cruise Missile)	*Air Force*	*Missile*	*1980*	*0.75*	*2.382*
ADDS (Aviation Digital Data Service)	*DoD*	*Electronic/ Automated Software*	*1980*	*0.306*	
AMRAAM	*Air Force*	*Missile*	*1980*	*4.672*	*6.225*
AN/BSY - 1	*Navy*	*Ship*	*1980*	*0.979*	
AN/BSY-2	*Navy*	*Ship*	*1980*	*0.979*	
ATACMS-APAM	*Army*	*Munition*	*1980*	*1.639*	*0.739*
ATARS (Aircrew Training and Rehearsal Support)	*Air Force*	*Electronic/ Automated Software*	*1980*	*0.163*	
AWACS RSIP (E-3)	*Air Force*	*Aircraft*	*1980*	*1.782*	*1.838*
B-2A	*Air Force*	*Aircraft*	*1980*	*0.987*	*0.987*
C-17A	*Air Force*	*Aircraft*	*1980*	*1.9*	*1.789*
CIS (MK XV IFF)	*Joint*	*Electronic/ Automated Software*	*1980*	*0.104*	
CMU	*Air Force*	*Electronic/ Automated Software*	*1980*	*1.092*	*1.092*
CSRL (Common Strategic Rotary Launcher)	*Air Force*	*Ordnance*	*1980*	*0.814*	*0.814*
CV HELO (SH-60F)	*Navy*	*Helicopter*	*1980*	*0.688*	*1.468*
DDG 51	*Navy*	*Ship*	*1980*	*81.236*	*11.972*
E-6A (TACAMO)	*Navy*	*Aircraft*	*1980*	*1.061*	*0.991*

APPENDIX: COMPLETE DATABASE BY RESPONSE OF INTEREST					
Program	**Service**	**Commodity**	**MS B Decade**	**MS B CGF**	**MS B PAUC CGF**
EJS (Enhanced JTIDS System)	*Air Force*	*Electronic/ Automated Software*	*1980*	*0.069*	
F/A-18A/B/C/D	*Navy*	*Aircraft*	*1980*	*0.961*	*1.095*
F-14D	*Navy*	*Aircraft*	*1980*	*0.342*	*3.276*
FDS (Fixed Distributed System)	*Navy*	*Electronic/ Automated Software*	*1980*	*0.208*	
FMTV (Family of Medium Tactical Vehicles)	*Army*	*Vehicle*	*1980*	*1.73*	*2.565*
HARM (NAVY)	*Navy*	*Missile*	*1980*	*1.601*	*1.03*
HHD-60	*Navy*	*Aircraft*	*1980*	*0.493*	*0.772*
I-S/A AMPE	*Air Force*	*Electronic/ Automated Software*	*1980*	*1.072*	*0.988*
JAVELIN	*Army*	*Munition*	*1980*	*1.019*	*0.568*
JSIPS (Joint Service Imagery Processing System) (CIGS)	*Air Force*	*Other*	*1980*	*0.917*	*0.917*
JSIPS (CIGS) Navy TIS	*Air Force*	*Other*	*1980*	*1.052*	*1.052*
JTIDS (AIR FORCE)	*Air Force*	*Electronic/ Automated Software*	*1980*	*0.069*	
KC-135R	*Air Force*	*Aircraft*	*1980*	*0.914*	*0.732*
LCAC (Landing Craft, Air Cushion)	*Navy*	*Ship*	*1980*	*1.739*	*1.146*
LHD 1	*Navy*	*Ship*	*1980*	*1.777*	*0.888*
LLLBGK	*Air Force*	*Ordnance*	*1980*	*0.175*	*3.152*
LSD 41 CARGO VAR	*Navy*	*Ship*	*1980*	*0.542*	*0.903*
MCM 1	*Navy*	*Ship*	*1980*	*1.034*	*1.034*
MHC 51	*Navy*	*Ship*	*1980*	*1.145*	*1.145*
NESP (Navy EHF Satellite Communications Program)	*Navy*	*Satellite*	*1980*	*0.944*	*0.849*
PLS (FHTV)	*Army*	*Vehicle*	*1980*	*0.302*	*1.75*
MLRS SADARM Rocket	*Army*	*Munition*	*1980*	*0.794*	
155mm SADARM Projectile	*Army*	*Munition*	*1980*	*9.512*	*1.312*
SRAM II / SRAM T	*Air Force*	*Missile*	*1980*	*0.407*	
SSN 21 / AN/BSY-2	*Navy*	*Ship*	*1980*	*2.839*	
T-45TS	*Navy*	*Aircraft*	*1980*	*9.794*	*13.175*
T-46A	*Air Force*	*Aircraft*	*1980*	*0.174*	*11.31*
TITAN IV	*Air Force*	*Missile*	*1980*	*6.315*	*1.619*

APPENDIX: COMPLETE DATABASE BY RESPONSE OF INTEREST					
Program	**Service**	**Commodity**	**MS B Decade**	**MS B CGF**	**MS B PAUC CGF**
Trident II Missile	*Navy*	*Missile*	*1980*	*1.102*	*1.441*
AIM-9X BLOCK I	*Navy*	*Missile*	*1990*	*0.51*	*1.449*
ATACMS-BAT	*Army*	*Munition*	*1990*	*0.251*	*4.453*
AV-8B REMANUFACTURE	*Navy*	*Aircraft*	*1990*	*1.041*	*1.013*
B-1 CMUP-COMPUTER UPGRADE	*Air Force*	*Aircraft*	*1990*	*0.985*	*0.994*
B-1 CMUP-JDAM	*Air Force*	*Aircraft*	*1990*	*0.962*	*0.967*
B-1B CMUP	*Air Force*	*Aircraft*	*1990*	*0.998*	*1.504*
Bradley Upgrade	*Army*	*Vehicle*	*1990*	*2.236*	*1.356*
C-5 AMP	*Air Force*	*Aircraft*	*1990*	*1.301*	*0.992*
EA-6B ICAP III	*Navy*	*Aircraft*	*1990*	*1.014*	*1.014*
Excalibur	*Army*	*Munition*	*1990*	*0.395*	*3.966*
F/A-18E/F	*Navy*	*Aircraft*	*1990*	*0.695*	*1.259*
F-22	*Air Force*	*Aircraft*	*1990*	*0.854*	*2.944*
GBS (Global Broadcast Service)	*Air Force*	*Satellite*	*1990*	*2.411*	*0.659*
H-1 Upgrades	*Navy*	*Helicopter*	*1990*	*3.327*	*2.639*
JASSM (Joint Air-to-Surface Standoff Missile)	*Air Force*	*Munition*	*1990*	*3.792*	*1.291*
JDAM (Joint Direct Attack Munition)	*Air Force*	*Munition*	*1990*	*4.389*	*1.035*
JPATS (Joint Primary Aircraft Training System)	*Air Force*	*Aircraft*	*1990*	*1.489*	*2.337*
JSOW BASELINE/BLU-108	*Navy*	*Munition*	*1990*	*3.172*	*14.075*
JSOW UNITARY	*Navy*	*Munition*	*1990*	*0.462*	*1.131*
LAND WARRIOR	*Army*	*Other*	*1990*	*0.269*	*9.769*
LONGBOW APACHE	*Army*	*Helicopter*	*1990*	*1.256*	*1.256*
LONGBOW APACHE	*Army*	*Helicopter*	*1990*	*2.379*	*2.382*
LPD 17	*Navy*	*Ship*	*1990*	*3.221*	*1.487*
MH-60R	*Navy*	*Helicopter*	*1990*	*2.42*	*1.625*
MH-60S	*Navy*	*Helicopter*	*1990*	*2.337*	*1.411*
MIDS (Multifunctional Information Distribution System)	*Navy*	*Electronic/ Automated Software*	*1990*	*4.387*	*0.585*
MINUTEMAN III GRP	*Air Force*	*Missile*	*1990*	*1.621*	*1.621*
Minuteman III PRP	*Air Force*	*Missile*	*1990*	*0.973*	*0.983*
NAS (National Airspace System)	*Air Force*	*Other*	*1990*	*1.836*	*0.501*

APPENDIX: COMPLETE DATABASE BY RESPONSE OF INTEREST

Program	Service	Commodity	MS B Decade	MS B CGF	MS B PAUC CGF
NSSL (National Security Space Launch)	*Air Force*	*Booster*	*1990*	*3.159*	*6.354*
PAC-3 (Fire Unit)	*Army*	*Missile*	*1990*	*0.448*	*0.605*
PAC-3 (Missile Segment)	*Army*	*Missile*	*1990*	*1.273*	*1.127*
SBIRS High	*Air Force*	*Satellite*	*1990*	*0.316*	*0.158*
SSN 774	*Navy*	*Submarine*	*1990*	*1.928*	*1.205*
STRATEGIC SEALIFT	*Navy*	*Ship*	*1990*	*0.92*	*0.92*
TOW-2	*Army*	*Missile*	*1990*	*0.985*	*0.988*
V-22	*Navy*	*Aircraft*	*1990*	*1.243*	*1.585*
AAG (Advanced Arresting Gear)	*Navy*	*Other*	*2000*	*1.07*	*0.803*
AESA (Active Electronically Scanned Array)	*Navy*	*Electronic/ Automated Software*	*2000*	*1.169*	
AGM-88E AARGM	*Navy*	*Missile*	*2000*	*1.34*	*1.301*
AH-64E Remanufacture	*Army*	*Helicopter*	*2000*	*1.629*	*1.535*
ASIP (Aircraft Structural Integrity Program)	*Air Force*	*Electronic/ Automated Software*	*2000*	*0.999*	*0.999*
AWACS Blk 40/45 Upgrade	*Air Force*	*Aircraft*	*2000*	*1.01*	*1.01*
B-2 EHF Inc 1	*Air Force*	*Aircraft*	*2000*	*0.8*	*0.84*
B-2 RMP	*Air Force*	*Aircraft*	*2000*	*0.989*	*1.038*
C-130 AMP (Aviation Modernization Program)	*Air Force*	*Aircraft*	*2000*	*0.609*	*35.135*
C-5 RERP	*Air Force*	*Aircraft*	*2000*	*0.777*	*1.673*
CEC (Cooperative Engagement Capability)	*Navy*	*Electronic/ Automated Software*	*2000*	*1.493*	*1.159*
CH-53K	*Navy*	*Helicopter*	*2000*	*1.657*	*1.334*
COBRA JUDY REPLACEMENT	*Navy*	*Ship*	*2000*	*1.106*	*1.106*
CVN 78	*Navy*	*Ship*	*2000*	*1.113*	*0.835*
E-2D AHE	*Navy*	*Aircraft*	*2000*	*1.767*	*1.541*
EA-18G	*Navy*	*Aircraft*	*2000*	*1.679*	*0.944*
EPF (Expeditionary Fast Transport)	*Navy*	*Ship*	*2000*	*0.551*	*1.193*
G/ATOR	*Navy*	*Other*	*2000*	*0.937*	*1.187*
GPS III	*Air Force*	*Satellite*	*2000*	*1.282*	*1.139*
HIMARS	*Army*	*Other*	*2000*	*0.464*	*1.089*

APPENDIX: COMPLETE DATABASE BY RESPONSE OF INTEREST

Program	Service	Commodity	MS B Decade	MS B CGF	MS B PAUC CGF
HMS (Handheld, Manpack & Small Form-Fit)	Army	Electronic/ Automated Software	2000	0.897	0.682
IAMD (Integrated Air and Missile Defense)	Army	Missile	2000	1.297	0.801
JOINT MRAP	Navy	Other	2000	1.126	0.898
JTN (Joint Tactical Network)	Army	Electronic/ Automated Software	2000	2.201	
LAIRCM	Air Force	Electronic/ Automated Software	2000	1.138	1.138
LHA 6	Navy	Ship	2000	3.799	0.95
MP-RTIP	Air Force	Electronic/ Automated Software	2000	0.8	
MQ-1C Gray Eagle	Army	UAV	2000	1.138	0.336
MQ-4C Triton	Navy	UAV	2000	1.136	1.136
MQ-8 Fire Scout	Navy	UAV	2000	1.317	3.329
MQ-9 Reaper	Air Force	UAV	2000	0.929	0.877
MUOS (Mobile User Objective System)	Navy	Satellite	2000	1.044	1.253
NMT (Navy Multiband Terminal)	Navy	Electronic/ Automated Software	2000	1.074	1.34
P-8A	Navy	Aircraft	2000	1.079	0.993
RQ-4A/B Global Hawk	Air Force	UAV	2000	1.268	1.437
SBSS BLOCK 10	Air Force	Satellite	2000	1.113	1.113
SM-6	Navy	Missile	2000	1.646	0.854
STRYKER	Army	Vehicle	2000	2.188	1.023
THAAD (Terminal High Altitude Area Defense)	DoD	System of Systems	2000	1	1
UH-60M Black Hawk	Army	Helicopter	2000	1.992	1.775
WGS (Wideband Global SATCOM)	Air Force	Satellite	2000	4.134	1.55
WIN-T Inc 2	Army	Electronic/ Automated Software	2000	1.069	1.248
ACV FoV	Navy	Combat Vehicle	2010	2.33	0.82
AMDR (Air and Missile Defense Radar)	Navy	Other	2010	1.043	1.147

APPENDIX: COMPLETE DATABASE BY RESPONSE OF INTEREST

Program	Service	Commodity	MS B Decade	MS B CGF	MS B PAUC CGF
AMPV (Armored Multi-Purpose Vehicle)	*Army*	*Vehicle*	*2010*	*1.166*	*1.166*
B61 Mod 12 LEP TKA	*Air Force*	*Munition*	*2010*	*0.749*	*0.749*
CIRCM (Common Infrared Countermeasures)	*Army*	*Other*	*2010*	*1.525*	*0.937*
DDG 1000	*Navy*	*Ship*	*2010*	*1.105*	*1.105*
EPS (Enhanced Polar System)	*Air Force*	*Satellite*	*2010*	*1.797*	*0.898*
ESB (Expeditionary Sea Base)	*Navy*	*Ship*	*2010*	*0.879*	*1.099*
F-15 EPAWSS	*Air Force*	*Other*	*2010*	*1.713*	*1.043*
F-22 Inc 3.2B Mod	*Air Force*	*Aircraft*	*2010*	*0.91*	*0.91*
F-35	*DoD*	*Aircraft*	*2010*	*1.006*	*1.006*
GPS IIIF	*Air Force*	*Satellite*	*2010*	*0.985*	*1.032*
HH-60W	*Air Force*	*Helicopter*	*2010*	*1.053*	*1.044*
ICBM Fuze Mod	*Air Force*	*Other*	*2010*	*1.202*	*1.156*
JAGM (Joint Air-to-Ground Missile)	*Army*	*Missile*	*2010*	*1.133*	*1.133*
JLTV (Joint Light Tactical Vehicle)	*Army*	*Vehicle*	*2010*	*1.04*	*1.04*
JPALS (Joint Precision Approach and Landing System)	*Navy*	*Other*	*2010*	*0.943*	*1.163*
KC-46A	*Air Force*	*Aircraft*	*2010*	*0.897*	*0.897*
LCS (Littoral Combat Ship)	*Navy*	*Ship*	*2010*	*0.628*	*0.987*
LCS MM (Mission Modules)	*Navy*	*Other*	*2010*	*0.904*	*1.181*
MGUE Inc 1	*Air Force*	*Satellite*	*2010*	*1.191*	*1.191*
NGJ Mid-Band	*Navy*	*Electronic/ Automated Software*	*2010*	*1.015*	*1.015*
OASuW Inc 1 (LRASM)	*Navy*	*Munition*	*2010*	*1.867*	*0.557*
OCX (Operational Control System)	*Air Force*	*Satellite*	*2010*	*0.996*	*0.996*
SDB (Small Diameter Bomb) II	*Air Force*	*Munition*	*2010*	*1.014*	*1.014*
Space Fence Inc 1	*Air Force*	*Other*	*2010*	*0.917*	*0.917*
SSBN 826	*Navy*	*Submarine*	*2010*	*1.002*	*1.002*
SSC (Ship to Shore Connector)	*Navy*	*Ship*	*2010*	*1.104*	*1.104*
VH-92A	*Navy*	*Helicopter*	*2010*	*0.947*	*0.947*

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Author Biographies

CAPT SAMMANTHA JONES, USAF

is a recent graduate of the Air Force Institute of Technology (AFIT), where she earned an MS in Cost Analysis. She is currently assigned as a cost analyst for the Air Force Life Cycle Management Center Enterprise IT and Cyber Infrastructure Division at Hanscom AFB, MA.

(E-mail address: sammantha.jones@us.af.mil)

DR. EDWARD D. WHITE

is a Professor of Statistics in the Department of Mathematics and Statistics at AFIT. He received his BS in Mathematics from the University of Tampa, an MS from The Ohio State University, and a PhD in Statistics from Texas A&M University. Dr. White's primary research interests include statistical modeling, simulation, and data analytics.

(E-mail address: Edward.White@afit.edu)

DR. JONATHAN D. RITSCHEL

is an Associate Professor of Cost Analysis in the Department of Systems Engineering and Management at AFIT. He received his BBA in Accountancy from the University of Notre Dame, an MS in Cost Analysis from AFIT, and a PhD in Economics from George Mason University. Dr. Ritschel's research interests include public choice, the effects of acquisition reforms on cost growth in DoD weapon systems, and economic institutional analysis.

(E-mail address: Jonathan.Ritschel@afit.edu)

MR. SHAWN M. VALENTINE

is an Operations Research Analyst at the Air Force Life Cycle Management Center/Financial Management & Comptroller Support Directorate at Wright Patterson AFB, Ohio. Mr. Valentine graduated from Ohio University with a BS in Actuarial Science and an MS in Financial Economics.

(E-mail address: shawn.valentine@us.af.mil)

SUCCESSFUL ADOPTION OF DevOps Practices IN SOFTWARE DEVELOPMENT IN DOD ACQUISITION PROGRAMS

The CREATE Example

Richard P. Kendall, Nathan S. Hariharan, David R. Sears, and Douglass E. Post

A growing number of articles describe the challenges of adopting DevOps for DoD software development. A recent paper in this journal discussed DevOps adoption challenges within the acquisition programs of the Navy. For embedded software, these challenges have been overwhelming to date. However, for standalone applications, the story is different, even though the lingering impact of DoD Instruction 5000 and other DoD cultural practices remains problematic. The HPCMP CREATE™ program, or simply CREATE in this paper, is part of the portfolio of the DoD High Performance Computing Modernization Program (HPCMP). It has successfully adapted DevOps concepts and agile software development practices to develop a family of software applications that enable system-scale virtual prototyping and testing analysis for major DoD acquisition programs. This study describes the main enabling practices that made this possible.

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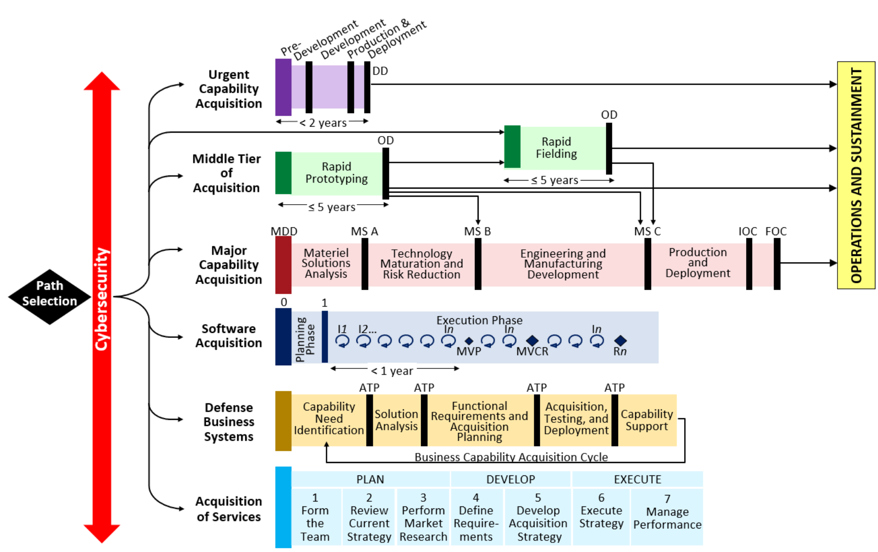
Image designed by Ken Salter

Several DoD advisory bodies, including the Defense Innovation Board (DIB, 2018) and the Defense Science Board (DSB, 2018), have pointed out that the DoD Instruction (DoDI) 5000 document series traces its roots back to 1971 (Ferrara, 1996), and its original focus was hardware acquisition rather than the optimal way to acquire or develop software. These boards and other DoD advisors subsequently urged the DoD to adopt the approaches of Silicon Valley and the modern commercial software industry. The DSB reintroduced the term "software factory" as the recommended model; it features Agile methods and a DevOps (now DevSecOps) approach. Moreover, the guidance in DoDI 5000.02 (Office of the Under Secretary of Defense for Acquisition and Sustainment, 2020) now acknowledges that software and hardware are different, and software development has its own path with "incremental" feature development and the release of minimum viable products (MVPs), as illustrated in Figure 1. Incremental development and MVPs lie at the heart of DevOps. (As stated in DoDI 5000.02, this is focused on acquired, not internally developed, software, but we believe that it applies to software used by acquisition programs whatever the source.)

FIGURE 1. DODI 5000.02 ADAPTIVE ACQUISITION PATHWAY SELECTION



Note. ATP = Authority to Proceed; FOC = Full Operational Capability; IOC = Initial Operational Capability; MDD = Materiel Development Decision; MS = Milestone; MVCR = Minimum Viable Capability Release; MVP = Minimum Viable Product.

However, this was not the case in 2008, when software development in the Computational Research and Engineering Acquisition Tools and Environments (CREATE) program began. DoD acquisition software development was then governed by the Capability Maturity Model and earned value management. At startup, CREATE was constrained by both.

Although software and hardware are, in many cases, tightly coupled within weapon systems (no modern military vehicle would be operable without software), this is not always the case. The development and use of virtual prototypes and digital siblings/twins is an important instance of this decoupling. These software constructs do not operate hardware. The CREATE program was started in 2007 by the Office of the Secretary of Defense to promote the use of physics-based virtual prototypes in the design and testing of complex weapon systems before physical prototypes are manufactured. In the 15 years since its inception, CREATE has sponsored the development of a family of 13 production-grade software applications for the following virtual prototypes:

- Naval combatants including submarines
- Fixed-wing aircraft for the Air Force and Navy
- Helicopters for all the Services
- Ground vehicles including tracked vehicles for the Army and Marines
- Radio-frequency antennas (radars) for applications that scale from an individual to arrays of antennas on aircraft carriers

Recent uses include the USS *Gerald R. Ford* (CVN 78) aircraft carrier, the replacement of the Ohio class of submarines, the B-52's engine upgrade, and the Army's future vertical-lift program (DoD High Performance Computing Modernization Program, 2023). This is production, not research, software.

CREATE software has been developed to augment and support physical testing, but it is not embedded within a hardware system.

While there are good reasons for the formalism embodied in the DoD Instruction 5000 series (henceforth just DoDI 5000) for hardware (e.g., high reliability requirements and the statute-bound nature of acquisition processes, like testing), it has been an impediment to software development in DoD. More significantly, Miller et al. (2022) found that the difficult-to-change cultural attitudes of the acquisition community, such as risk aversion and cost avoidance, persist despite the evolving guidance in DoDI 5000. The objective of this case study is to describe how CREATE structured its implementation of DevOps to address the challenges of earlier hardware-centric versions of DoDI 5000 and other persistent DoD cultural obstacles like those cited earlier.

DevOps

The term "DevOps" describes an Agile software-development approach that does not end when the software is released, but extends to the operational phase, abbreviated as "Ops," which supports the delivery and implementation of the software. DevOps has evolved into DevSecOps (splunk, 2021). According to the DoD Chief Information Officer (2019), "the main characteristic of DevSecOps is to automate, monitor, and apply security at all phases of the [DevOps] software lifecycle: plan, develop, build, test, release, deliver, deploy, operate, and monitor" (p. iv). We will address "Sec" in a subsequent paper.

These are the main objectives of DevOps (DevOps Manifesto, 2018):

- Faster product delivery without sacrificing quality
- Faster response to customer needs
- Better working environment for developers and customers

These are some of the main attributes of the DevOps approach:

- *Culture*
    - *Constant collaboration*—team and customer cohesion are important
    - *Shared end-to-end responsibility*—success cannot be compartmentalized
    - *Early problem-solving*—referred to as "fail early" among practitioners
- *Automation of processes*—automation of development, integration, configuration, testing, and deployment to the greatest extent possible
- *Agile planning*—concentrate on the immediate; sketch out the high-level objectives to speed up delivery
- *Continuous development*—think of this as taking iterative development to the limit
- *Continuous integration, delivery, and deployment*—code that passes tests is automatically integrated into a shared repository (part of the six "Cs" of the DevOps approach)
- *Infrastructure as Code*—a code management approach that allows the testing of the infrastructure in the same way code is tested (e.g., a virtual machine that behaves like the production environment)

In 2008, implementation of many of the features of DevOps seemed unlikely due to the cultural environment of DoD and the constraints imposed by DoDI 5000. The foundational tenets of Agile development inherited by DevOps were orthogonal to the native culture of DoD (not just that of the DoD acquisition community). CREATE encountered this cultural disconnect from the beginning. For example, *constant collaboration* between software developers and their customers implies a level of trust that is rarely present between DoD customers and providers (this was also cited by Miller et al., 2022). Also, software providers need to protect their intellectual property, and they are usually unwilling to share important details of the software with their DoD customers (Post & Kendall, 2021). The notion of *shared responsibility* implies shared risk, and the acceptance of risk is anathema in DoD (and often fatal in acquisition programs). The concept of "fail early"—to promote earlier, easier correction—has the potential to foster the ultimate risk: early cancellation of the program. Yet failure in software is the norm, not the exception. For example, according to a recent report (Standish Group International, 2022, p. 6 [behind a paywall, but verified]), 49 percent of software projects similar to the proposed new one they analyzed were failures, 47 percent were "challenged"—meaning over budget or time—and only 4 percent were successful.

Study Approach

This case study is primarily based on written documentation available from the CREATE project from start-up to the present. Some of it has been published and will be cited later. The project goal was to identify the main barriers to adoption of Agile practices that we now identify with DevOps and the structure of the practices that were chosen to address these obstacles. The emphasis will be on how CREATE implemented these practices to accommodate cultural expectations in DoD acquisition.

The earliest documents were a collection of case studies that the principals of CREATE had conducted prior to the start of CREATE. These are summarized in Table 1.

TABLE 1. CASE STUDY BACKGROUND FOR CREATE

Source	Program/Organization Studied	Study Focus
Post & Kendall (2004)	*Accelerated Strategic Computing Initiative (DOE)*	*Program management lessons learned from 6-code ASCI software development projects. These projects were very similar to CREATE and involved replacing nuclear-weapons testing with simulation.*
Carver et al. (2007)	*Various DoD HPC Software development environments (DoD)*	*Life cycle, workflows, technical and organizational challenges in HPC programs in DoD.*
Kendall et al. (2008)	*Weather Forecasting (DoD)*	*Identifying critical success factors, including steps to make the code development process more productive in DoD, sponsored by DARPA.*

Note. ASCI = Accelerated Strategic Computing Initiative; DARPA = Defense Advanced Research Projects Agency; DOE = Department of Energy; HPC = High Performance Computing; IEEE = Institute of Electrical and Electronics Engineers.

Generally, these studies focused on identifying barriers to the adoption of emerging Agile software engineering practices by government scientists and engineers developing physics-based, high-performance computing applications. These barriers included the then-widespread influence of the Capability Maturity Model in government software development. It is important to remember that Agile methods themselves did not have the acceptance by the technical software community in 2006–2008 that they do now. Practices that are now commonplace were novel then in science-based software development.

These case studies informed CREATE's first documented attempt to address the perceived software development obstacles identified in the studies cited in Table 1, the *CREATE Software Engineering Practices and Processes* (2009). The initial focus was on Agile practices because the term "DevOps" itself had not yet been coined. This first guide had two successors, the *CREATE Business Plan* (2014) and the *CREATE Operational Practices Guide* (2021).

All these documents received DoD approval for public release. Portions of them were also published in the IEEE software engineering journal, *Computing in Science and Engineering*. Specific references to these journal articles will appear later, as they are important sources for the "data" of our study (i.e., the obstacles and the practices).

> **It is important to acknowledge that CREATE software development has primarily been accomplished within DoD Service research and development (R&D) organizations that are not necessarily subject to DoDI 5000 constraints in R&D work in acquisition programs.**

From these sources we can track the focus on aligning CREATE development with DevOps. Additionally, the CREATE program assessed the progress toward adoption of DevOps practices with three surveys (unpublished), conducted in 2012, 2014, and 2017, and followed by detailed interviews. What follows is a synopsis of the specific obstacles identified by the CREATE program and the mitigating practices that have allowed CREATE to reach what we believe is a credible implementation of DevOps across the program.

It is important to acknowledge that CREATE software development has primarily been accomplished within DoD Service research and development (R&D) organizations that are not necessarily subject to DoDI 5000 constraints in R&D work in acquisition programs. Nevertheless, CREATE was compelled to acknowledge and address them, since acquisition programs were (and are) the main consumers of CREATE software. CREATE development has taken place inside the Defense Research and Engineering Network (DREN) enclave with strong network security and highly controlled access, which both vetted developers and customers use (generally, they have clearances).

The federated nature (multiple organizations with a central management) of the CREATE program, consisting of some 30 participating organizations spread across the U.S. Armed Services, made this a challenge. It was clear to CREATE's management that the heterogeneous working environments of the Services would likely preclude any completely uniform approach across CREATE. For example, in the beginning only one of the CREATE project teams was following an approach that could be characterized as "Agile." Over time, all the others realized its benefits and migrated to this approach.

Analysis and Findings

The goal here is describe the main obstacles identified by the founders of CREATE to the implementation of DevOps due to DoDI 5000 and other cultural practices and the ways that CREATE implemented DevOps-based practices to address them. The documents described in the previous section provide a more complete account of the full implementation of DevOps in CREATE.

The Main Obstacles to DevOps Implementation Encountered by CREATE

The obstacles inherent in DoD management practices identified at launch are listed in Table 2. These first appeared in CREATE Software Engineering Practices and Processes and were published in a 2016 study by Kendall, Post, et al. (p. 42).

TABLE 2. CORE PERCEIVED SOFTWARE DEVELOPMENT OBSTACLES FOR CREATE AT START-UP (2007-8)

1.	The challenge of creating and inventing new, innovative software technologies within the DoD conforming to the milestone-plan/earned-value management approach
2.	Relying on independent development teams embedded in and part of the relevant DoD customer organizations (where will their priorities be?)
3.	Team and customer communications and programs coordination within the diverse Service management cultures—especially security management cultures
4.	The threat that frequent turnover of senior DoD decision-makers poses to long-term stakeholder support (will the next acquisition program manager favor something else?)
5.	Control of intellectual property (no copyright in DoD that automatically protects software artifacts)
6.	Inability to support CREATE software users due to general lack of support (as opposed to development) for software in DoD, including the absence of career paths for software support staff

The CREATE management team recognized that most of these obstacles could not be overcome at start-up. Over time, the earlier items on the list, for example 1 and 2, have become less important, and the later ones, such as 4, 5, and 6, have become more important. This list is not comprehensive; additional obstacles were addressed in Post (2021), but they were unrelated to the DoDI 5000 or DoD acquisition culture.

How CREATE Addressed the Obstacles

As pointed out earlier, the CREATE management team recognized that it was not feasible to use a textbook implementation of an Agile workflow management method like Scrum to support DevOps. To have any hope of success, the CREATE implementation of Agile development methods, and ultimately DevOps, would have to be flexible—that is, the adoption of Agile practices would have to be agile.

Flexible Requirements Management that Addresses Acquisition Expectations

One of the most serious DoDI 5000-related cultural concerns is the management of software requirements. The historical expectation within the DoD acquisition community has been that the requirements must be nailed down before any work starts. In contrast, the Agile software development approach concentrates on the near-term and iterates to increasing capability through a series of MVPs that deliver incremental value continually. The idea that there is a "final" product is a fallacy, even though it is a cherished expectation of many software consumers. As the DSB stated, "Software never dies" (DSB, 2018, p. 3). The development of scientific/engineering codes often does not end until there are no users for the software. There are many examples of engineering codes that have been maintained and enhanced for more than 50 years (for example, NASTRAN, first released in 1968).

To address the disconnect, CREATE adopted the following DevOps-inspired practices (Kendall, Post, et al., 2016). These are examples of the adaption of DevOps-based practices that strive to accommodate cultural expectations in DoD acquisition.

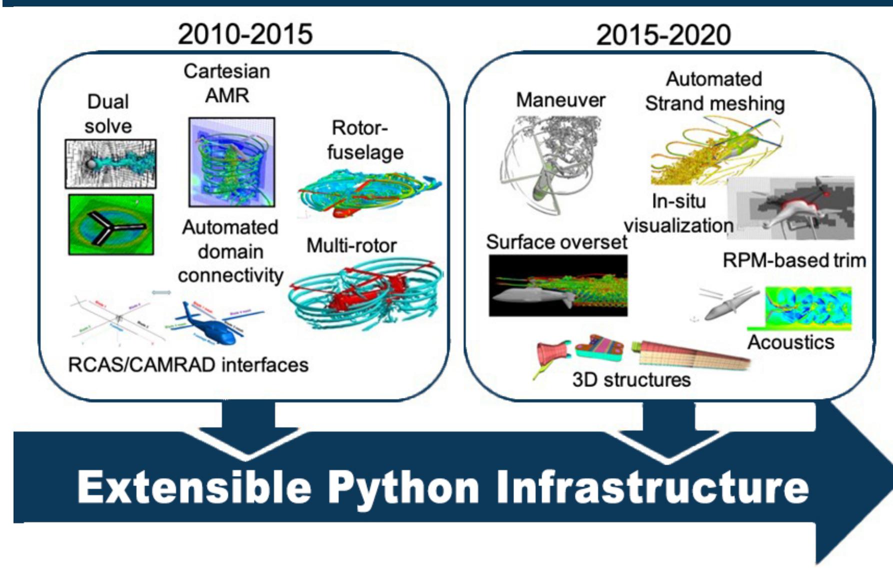
Practice: Form boards of directors (BoDs) from senior members of the DoD acquisition community (representing customers like Naval Air Systems Command, Naval Sea Systems Command, Air Force Sensors Directorate, Air Force Life Cycle Management Center, U.S. Army Combat Capabilities Development Command, and other acquisition customers) to provide high-level direction.

Frequent direct involvement of the DoD customer in formulating the requirements has turned out to be critical. CREATE's BoD members have their fingers on the pulse of acquisition in their organizations. With input from the BoDs and customer users, the CREATE product teams lock down the main deliverables for the ensuing fiscal year. Although declaring in advance the main deliverables for the coming fiscal year is not the backlog management practice envisioned by Scrum, it nevertheless does not lock the development teams into a fixed order of execution like milestone-plan methods. Importantly, this approach addresses the DoD stakeholders' concern about not knowing what they will get for the funding, at least on a fiscal year basis. Longer term forecasts of deliverables are addressed in the next practice.

Practice: If the program will not have a fixed termination date, develop roadmaps that describe the expected features of the software projected at least 10 years ahead (based on customer needs), the Board of Directors' review, and expected technology advances.

Even a simple visual roadmap like the one illustrated in Figure 2 can be reassuring about the future direction of the software. It also conveys the expected time scales for software feature evolution. Roadmaps also help to capture the fact that the future for complex software is not entirely predictable and cannot be precisely defined well in advance.

FIGURE 2. EXAMPLE ROADMAP FOR THE CREATE ROTARY-WING VIRTUAL PROTOTYPING APPLICATION, HELIOS



Note. AMR = adaptive mesh refinement; CAMRAD = Comprehensive Analytical Model of Rotorcraft Aerodynamics and Dynamics; RCAS = Rotorcraft Comprehensive Analysis System; RPM = rotations per minute.

CREATE has the tremendous advantage that many of its customers and developers are part of the same organizations. They are not at arm's length, as is more typical in DoD. This dramatically improves the quality of communication between them, making the following practices easier to implement.

Practice: Use prototypes and pilots to capture difficult-to-express requirements.

Prototypes and pilots help developers clarify difficult-to-express requirements. They give users early access to the developers' interpretation of the requirements. Pilots, using fully tested code, help ensure that customers can determine the value of the code in a setting they are most comfortable with—their own workflows. Both provide valuable feedback that allows development teams to address any miscommunication before a release. They are examples of the capture of requirements iteratively in software instead of text. This was an important accommodation—working software instead of the expected detailed software specifications. In addition, pilots help with verification (did we build the right software?), and validation (did we build the software right?).

Performance Tracking that Builds Confidence

Performance tracking was another obstacle to the successful implementation of DevOps identified early by CREATE. The CREATE program started by attempting to use the earned value management (EVM) approach expected by DoDI 5000. It was a painful experience, and ultimately unsuccessful. To be successfully applied, EVM depends on timely and accurate cost accounting and level-of-effort data. It was impossible for CREATE to collect this data in a timely way across the federated program due to the differences between each Service's accounting system. The EVM process itself also had to be tailored to the flexible execution of workflow tasks characteristic of DevOps. This forced constant rebaselining defeated the intent of EVM. The fundamental issue is that EVM is a tool for measuring the progress of a manufacturing process, not software development.

> **An initial concern about CREATE was that it had no billets, and therefore no employees, meaning it would have to rely on outside partners with potentially conflicting priorities for everything.**

The achievement of the DevOps goal of speeding up delivery of software releases went a long way toward addressing the concern about the demise of earned value accounting. CREATE now has a highly automated software development pipeline that often delivers three or four releases a year for many of its very complex products. This pipeline implements the automated continuous integration, delivery, and deployment feature of DevOps. The actual delivery of a promised feature is far more convincing than an estimate of current status, characteristic of EVM.

Practice: Release new features as frequently as feasible, but at least annually. (Kendall, Post, et al., 2016)

Development Teams Embedded in Customer Organizations

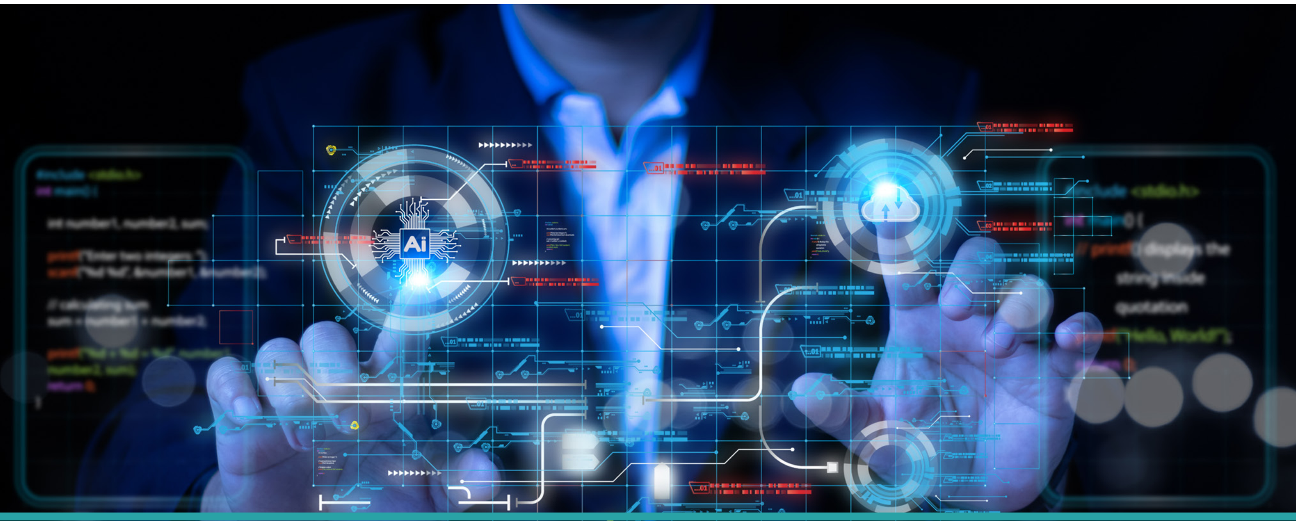
Although this was considered a potential obstacle at first, it has turned out to be a major success factor for CREATE. An initial concern about CREATE was that it had no billets, and therefore no employees, meaning it would have to rely on outside partners with potentially conflicting priorities for everything. This has proven not to be a problem. Having customer employees develop software tools that their organizations want to use has made the DevOps goal of constant collaboration feasible. If there has been an issue, it has been the ease of communications within and between Service organizations themselves. Different sites within the same organization often have security policies in place that hinder communications. We will touch on this again.

Secure Program Coordination and Team Communication Across Diverse DoD Security Cultures

CREATE, as a tri-Service program, needed to be able to work effectively across Military Service boundaries. Each of the Services has its own culture and processes that vary even among their components (e.g., Naval Sea Systems Command (NAVSEA) vs. Naval Air Systems Command (NAVAIR)). Different security policies across the Services have inhibited the development and use of CREATE software in some cases. Examples include policies that prevent client software installation and place restrictions on network ports and protocols and prohibition of any form of videoconferencing.

Most Service employees, including engineers who might use CREATE software, are limited to Windows-based PCs, and “approved” applications, including a browser. The fact that they cannot install software effectively prevents most potential users from gaining direct access to the CREATE software. As an alternative, the CREATE program and its parent, the DoD High Performance Computing Modernization Program (HPCMP), developed a web-based portal that allows secure access to the HPCMP systems, providing access to CREATE software through a browser. This access is allowed using multifactor authentication (MFA) and encrypted data transfers. Engineers with access to the Army, Navy, or Air Force networks can do the following:

- Access the HPCMP supercomputers through their browsers
- Establish a remote desktop
- Set up their problem
- Execute jobs
- Store the results
- Visualize and analyze the results in-situ
- Download the summary conclusions, including graphics and videos



The HPCMP Portal integrates various forms of help, community forums, and tutorials with the use of the tools themselves. CREATE is working toward getting its software approved for installation on DoD desktops, but the portal provides an interim solution for access to the software without requiring any local installation (Kendall, Votta, et al., 2016, p. 40). This is an instance of the following CREATE practice:

Practice: Establish a method for allowing developers and users to access the CREATE software through a browser on their Army, Navy, or Air Force systems.

Regarding program coordination, the HPCMP Defense Research and Engineering Network (DREN) team has established and supports a high-definition video-conferencing capability with high-quality audio that has greatly facilitated communication among and within the development teams and with the CREATE program Office. DREN provides highly secure, high-speed hardware-encrypted data transmission between all resource endpoints to ensure data integrity.

Turnover in Senior DoD Management that Threatens Stakeholder Support

In federal programs, both sponsors and customers are usually stakeholders—often not in the same organization. Senior DoD civilian and military leadership is fluid, with frequent and periodic changes due to retirement and advancement. Due to these frequent changes in leadership, CREATE must provide a constant upward flow of information and education as to the importance and necessity of the program. Otherwise, these changes jeopardize the success and existence of every CREATE project and the CREATE program as a whole. As part of this "upward flow of information," CREATE leverages its boards of directors, and continually meets with and informs new stakeholder's representatives to ensure their support.

Practice: Continually reach out to new senior and middle-level members of the DoD acquisition engineering community (government and industry) to acquaint them with the potential of CREATE to improve acquisition customer outcomes. Maintain relationships with those who supported CREATE but have moved to new responsibilities. (Kendall, Votta, et al., 2016)

There must be an ongoing strategic outreach activity due to the frequent turnover of senior DoD civilian leaders and military staff during the CREATE life cycle. In general, budgets in the DoD are a zero-sum game. Every new DoD leader has new ideas that usually require starting new programs. New programs require funds that generally must be diverted from existing programs. It is thus essential to be able to convince the new leadership that your program is more valuable than the competitors. To lose

your program, you only have to lose that argument once. This is another example of tailoring a DevOps practice to the DoD acquisition environment.

Control of Intellectual Property Rights

The CREATE software tools are military assets designed to provide the DoD with a military competitive advantage. Whereas a business can protect its intellectual property with patents, copyrights, and trademarks, a DoD enterprise like CREATE cannot take advantage of patents without exposing sensitive information that would compromise the government's military competitive advantage. Also, federal employees do not automatically receive a copyright for their work products. To cope with these limitations, CREATE adopted the following three practices.

Practice: Require a Standard Software Distribution Agreement (a license for use).

A license agreement confers two important benefits:

- Clearly specified restrictions on the use of the code (such as not selling, sublicensing, transferring, reverse compiling, or reverse engineering the code)
- Provides a warning that the CREATE software and associated materials are export-controlled under the International Traffic in Arms Regulations

Practice: Trademark the CREATE software.

If DoD and its contractors were the only users, this might not be necessary. However, CREATE software has been licensed to commercial companies. The use of a trademark identifies the CREATE software as government-owned and provides a basis for removal of the CREATE name from unauthorized copies or modifications of the software.

Practice: Acquire the necessary software rights in contracts and licenses.

All the contracts for developing CREATE software include the Defense Federal Acquisition Regulation Supplement (DFARS) clauses that grant unrestricted distribution rights to the DoD. Like most modern software, third-party open-source libraries are used to augment functionality within CREATE applications. A single instance of code included in CREATE tools without review and approval of license agreement validity could jeopardize the ability to distribute the application, cause the government to lose the right to use the application, and subject the government to legal action to recover alleged "damages" for violating license restrictions. Consequently, all third-party licenses are reviewed to determine whether distribution of CREATE will be inhibited by any license restrictions, copyrights, or patents. If necessary, new licenses are negotiated or alternate software is licensed or developed internally. An audit is performed before release to verify that all the terms of the third-party licenses are acknowledged before releasing derivative or extended software.

The use by CREATE of contracts without the proper DFARS clauses could result in limitations on government rights to distribute the software. If the government pays for 100 percent of the software development effort, CREATE insists on unlimited use rights. When software development has been only partially funded by the government, CREATE receives government purpose rights. The government retains exclusive, irrevocable rights to use software developed by a contractor in accordance with DFARS.

Supporting CREATE Users

Supporting the distribution and use of software is a key element of the DevOps approach. However, obtaining funding for user support within DoD has documented challenges (Post & Kendall, 2021). Senior decision makers, who control funding and who easily support funding for the support of a physical facility (e.g., a wind tunnel), do not as readily accept the need for sustained funding for user support for software. In most DoD organizations that we have had experience with, there is no career path for individuals who support software but do not develop it or use it. The requests for funding for user support are taken seriously only after the tools have convincingly proved their value, when it may be too late.

CREATE has dealt with this problem with several approaches. One has been to rotate developers through product support teams. This not only provides developer-level support for the user, which most software organizations are ordinarily loath to provide, but it also provides developers with insights into how users experience the software.

A second approach has been to outsource software support to contractors who view support as a business. In this case, it is valued as a primary deliverable.

The third approach has been to maximize self-help in the product support model. One of the most successful examples of this is the cultivation of "local" expert users within customer organizations. Web-based user forums can also help—at least to the extent that they provide easy access to other users, including experts. One of CREATE's goals is to make the typical user, but especially groups of users in the same organization, as self-sufficient as possible. Along with web-based user forums, user documentation, online tutorials, and test data sets help achieve this goal. Online tutorials and user forums offer a scalable way to support a growing customer base. These approaches are examples of the following practice:

Practice: Look for innovative ways to ensure quality user support.

Conclusions

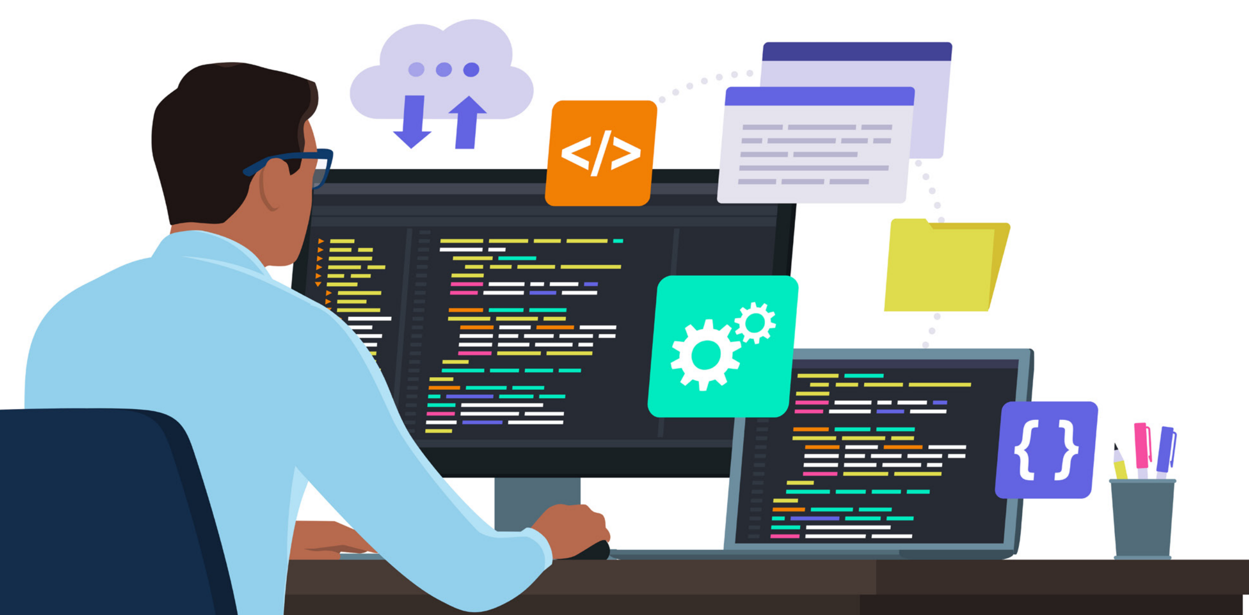
Confronted with rapidly changing technology and requirements, the founders of the CREATE program believed, based on studies of similar projects, that the DevOps approach to software development offered the best way to deliver value "at the speed of relevancy" to its DoD acquisition customers. However, hardware-focused DoD Instruction 5000 and other cultural artifacts of the DoD acquisition enterprise posed challenges to the adoption of DevOps by any software development program targeting acquisition customers. These obstacles have been largely surmounted by the CREATE program in its development of software for virtual prototypes, digital surrogates and twins, and the digital thread for DoD. This was accomplished by adapting a set of DevOps-promoting practices that addressed both the intent of DoD 5000 and the obstacles presented by DoD acquisition culture. CREATE's contribution is not the practices themselves, but the way they are formulated to meet DoD acquisition expectations. We offer this as an example of how it can be done.

Summary of the practices:

- *Form boards of directors from senior members of the acquisition community.* Customer oversight goes a long way towards cementing customer buy-in, a DevOps principle, within an inherently cautious customer base.
- *Express requirements in language that stakeholders, customers, and developers all understand.* This would include software prototypes that capture feature specifications in working code.

- *Develop roadmaps that project at least 10 years of future direction.* This helps to reassure DoD acquisition customers without over specifying future development that cannot be precisely defined—another DevOps principle.
- *Continually reach out to senior- and middle-level DoD acquisition leaders.* This is necessary to ensure stakeholder support from frequently changing DoD Service and civilian leadership.
- *Trademark the software, acquire all necessary rights to third-party components, and require a standard software license for use of the software.* This helps to protect the DoD's interests since government software cannot be copyrighted and is patented only reluctantly due to disclosure requirements.
- *Look for innovative ways, especially using the Web, to ensure quality user support.* User support is central to "Ops" in DevOps and is essential to long-term success, but it is difficult to provide in the DoD software environment that limits the installation of software.

DevOps has been key to the rapid development, deployment, and successful use of the CREATE family of virtual prototyping tools by DoD programs.



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Author Biographies

DR. RICHARD P. KENDALL

is a software engineering consultant with the CREATE program. His career began in industry (Esso Production Research), followed by a stint as Senior VP at a software start-up, and since 1995 in government (DOE and DoD). Dr. Kendall received BA and MA degrees in Mathematics from UT Austin, followed by a PhD in Mathematics from Rice University. He is a member of IEEE and SPE/AIME with publications in numerical analysis, petroleum engineering, and software engineering.

(E-mail address: richard.kendall13@icloud.com)

DR. NATHAN HARIHARAN

is the Director for Technical Development and Operations for the CREATE program and one of its principal architects. He holds a BS in Aerospace Engineering from the Indian Institute of Technology, Madras, and an MS and a PhD in Computational Engineering from Georgia Tech. He has published over 100 technical articles and is an Associate Fellow of the AIAA, chair of the AIAA Rotorcraft Simulation Group, and vice-chair of the Applied Aerodynamics Technical Committee.

(E-mail address: Nathan.Hariharan.ctr@mail.mil)

MR. DAVID R. SEARS

is the Deputy Director for Security and Operations for the CREATE program. He has over 35 years of professional experience with government and industry in various scientific and leadership roles. He received a BA in Mathematics from Tennessee Temple University and MS in Systems and Control Engineering from the University of West Florida. He is also a Certified Secure Software Lifecycle Professional (CSSLP) and a 2018 graduate of Air Command and Staff College.

(E-mail address: david.r.sears@erdc.dren.mil)

DR. DOUGLASS E. POST

was the founding CREATE program Director. He served as Principal Researcher at the Software Engineering Institute, Chief Scientist of the DoD High Performance Computing Modernization Program; led computational programs at LLNL, LANL, PPPL, and ITER; and served as Associate Editor-in-Chief of IEEE's *Computing in Science and Engineering*. He is a Fellow of APS, ANS, IEEE; an associate Fellow of the AIAA; and a recipient of the 2010 ASNE Gold Medal.

(E-mail address: serenoroad@verizon.net)

Image designed by Ken Salter

A TALE OF TWO ORGANIZATIONS: A Qualitative Comparative Study OF CONTRACTING ORGANIZATIONS

Jennifer W. Elkins

The Department of Defense has long focused on reform for increased performance, decreased cost, and decreased schedule. The author investigated the differences between those within the acquisition contracting community exercising the new authorities provided in the Adaptive Acquisition Framework and those operating in a traditional acquisition environment through qualitative comparative analysis surrounding the characteristics of bureaucracy. Using the established framework of the Theory of Planned Behavior, the author evaluated interview responses to gain a deeper understanding of participants' lived experiences, thereby discovering those attitudes, perceived behavioral controls, and social pressures most prevalent and influential in evaluating behavior for the two types of organizations. Results indicated significant differences between the two types of organizations, with a strong alignment of traditional contracting organizations with the characteristics of bureaucracy and practical implications for leaders seeking to drive innovation within their organizations.

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As relations with Russia and China have shifted to a new Cold War status and impacted the landscape of strategy (Mastel, 2022), the need for innovation within the Department of Defense (DoD) and public administration overall has become more pressing than ever. For nearly six decades, the DoD has struggled to reform the cost, schedule, and performance within the acquisition enterprise to little avail (Fox, 2011). Some measures taken include targeting fraud; centralizing and then decentralizing decision authorities; improving the acquisition and contracting workforce hiring, training, and development initiatives; and infusing private-sector business practices (Weinig, 2019). While innovations are ongoing, the traditional weapon system acquisition cycle still takes an average of 15–20 years, and the rapid acquisition cycle takes 7–10 years to field (Arthur, 2018; Schoeni, 2017). Further, overages for baseline projections of weapon systems from 1968 to 2017 averaged -2.9% of GDP, with a deficit nearly every year (Arthur, 2018). Desired schedule and programmatic outcomes are known to be affected by government acquisition community behaviors; however, research has also noted that while buyers have a desire for rapid procurement, they are also pushed toward competition and innovation through statute and policy, creating additional risk (Etemadi & Kamp, 2021).

Acquisition reform initiatives improved outputs somewhat. Still, issues have impacted the DoD's retention of progress in the long term, including wide swings of perspective across changing political administrations with contradictory priorities (Hunter, 2018). Successful implementation of change often relies on the organizational structure and tendencies of organizational culture, such as behavioral momentum, regression to the mean, inadequate behavioral developmental stage for addressing issues, and interaction among these variables (Commons, 2018). Research indicates that cultural tendencies or social norms related to innovation throughout the DoD are segmented by the differing behaviors of two types of acquisition organizations: technology enablers, or those with an innovation focus, and traditional, or those with a traditional Federal Acquisition Regulation (FAR) focus (Elkins, 2022).

For nearly six decades, the DoD has struggled to reform the cost, schedule, and performance within the acquisition enterprise to little avail.

Past studies have indicated that organizations implementing disruptive technology and innovative thinking can be affected and sustained within DoD acquisition (Bonvillian, 2018); however, these organizations are few. Bonavillian identified project managers in innovation organizations, such as Defense Advanced Research Projects Agency (DARPA) and Advanced Research Projects Agency-Energy (ARPA-E) as "technology enablers." These entities have imperatives to remove barriers and create networks to bridge the stovepiping of technology insertion (Bonvillian, 2018). Support networks have significant roles for technology enablers to ensure the success of innovation activities (Bonvillian, 2018), implying that the innovation organization is the technology enabler as a whole rather than only the project director. While research has shown that government innovation organizations fill three primary roles—networkers; educators; and acquisition facilitators, investors, accelerators, or developers—their metrics are referred to from a project-specific focus (Brunelle et al., 2020). The distinct behavioral roles within these organizations represent a factor that has not been significantly studied and may present researchers and managers alike with a tool that promotes better understanding of what makes these organizations different and a factor to further contribute to the study of Organizational Behavior Theory.

The problem to be addressed by this qualitative study is the management challenge of implementing successful change in DoD acquisition organizations. Academic studies estimate that 40 to 90 percent of innovative projects fail in whole or in part (Rhaiem & Amara, 2019). While the bureaucratic nature of public sector administration and its effect on innovation has been extensively studied (Lapuente & Suzuki, 2020), the influence of bureaucratic behaviors within contracting and acquisition organizations has not. Contracting organizations are heavily bureaucratic by design due to their key responsibilities of being the last line of defense to ensure fairness and

protect the taxpayer. This tendency towards bureaucratic design provides an incentive to lean toward risk reduction rather than mitigation or acceptance. More recently, a particular focus has been placed and resourced to press innovation within contracting communities, with constructs such as AFWERX (the Air Force innovation arm) and the procurement innovation laboratories seeking to infuse innovation into the behaviors within more traditional FAR-type organizations. The DoD needs to understand how these innovation cells can be more widely and successfully implemented and what factors may impede these efforts.

The purpose of this qualitative study is to investigate and compare the bureaucratic behaviors present within contracting organizations to understand better what characteristics of bureaucracy (Udy, 1959) are exhibited within the two types of DoD acquisition organizations: technology enabling and traditional. Additionally, this study determined the differences between these two types of organizations. Past research determined design thinking behaviors within the two types of organizations (Elkins, 2022). This research will provide a baseline for comparison for future causal research on the limitations of the implementation of design thinking and innovation in a greater context within the DoD.

Theoretical Framework and Hypothesis

The DoD began with a culture of disruptive innovation. For instance, the Wright Brothers began flight demonstrations in 1909 (Cooley & Dougherty, 2021). Within 10 years, the military had not just used or innovated within the technology space; it had begun implementing innovative strategies surrounding the new technology, such as developing reconnaissance and air-to-air fighter mission sorties in World War I (Cooley & Dougherty, 2021). The game-changing technology of aircraft in World War I appears to mirror the technological shifts for hypersonic technologies today; however, the DoD has not shifted the culture to address these critical challenges. Further, the differentiated business relationships to which these technological shifts are made possible have only been reviewed in a limited capacity.

Even while understanding the need for this disruptive technology, as evidenced through their outreach activities through innovation groups, such as Defense Innovation Unit (DIU) and AFWERX, the DoD continues to program for new technologies in the same way as the traditional weapon system constructs. Programs of record requiring lengthy development cycles, stovepiped research agencies creating research that languishes in the "valley of death," and budgeting cycles that require years to fund new program starts are examples of such constructs. Congress provided new acquisition authorities to the DoD, including other transaction authorities for prototyping, procurement for experimental purposes authorities, and rapid prototyping, among others identified within the Adaptive Acquisition Framework (Lord, 2020). These authorities aimed to obtain disruptive innovation through changes to business models, regulations, policy, formal institutions, behaviors, practices, and cultural models by dismantling current systems to incorporate innovation and commercial practices. Further, authority to use these different models was written into legislation for use to the "maximum extent" (Authority of the Department of Defense, 2021). However, implementation has been limited, representing only 1 percent of contracts executed (Peters, 2019), implying a reluctance to shift culture. Recent reports show that four of the five top recipients of other transaction authority awards went to consortiums (McCormick & Sanders, 2022) rather than high-technology nontraditional defense contractors and small businesses the statute was intended to reach. The remaining vendor was a top-five large business traditional defense contractor (McCormick & Sanders, 2022).

While the result of disruptive technology is the product that changes the marketplace, the four primary pathways for disruptive technology insertion are (a) markets and business models; (b) regulation, policy, and formal institutions; (c) actors and networks as a disrupted dimension; and (d) behavior, practices, and cultural models (Kivimaa et al., 2021). These four areas present a framework for understanding the underlying motivations to perform or inhibit a particular activity and may be effected to propel or impede innovation in the DoD enterprise.

> **The bureaucratic theory was developed by Max Weber in the 1800s and held that rational processes flowing from logic, efficiency, and reason enable efficient leadership power.**

Specific organizations such as DARPA, DIU, and NASA have been more successful in applying business approaches leading to these disruptive innovations (Bonvillian, 2018; Lifshitz-Assaf, 2018). These organizations have utilized unique approaches and differentiated processes through the use of unique authorities such as 10 U.S.C. § 4021 and Public Law 111-314. Successful organizations in this field are specialized clusters for innovation or technology enablers and are noted to have four primary characteristics: (a) the creation of innovation organizations, (b) the creation of an island/bridge construct where teams are protected from the bureaucracy and can accept more significant risk, (c) the creation of a thinking community, and (d) a link from the technologists to the operators or users (Bonvillian, 2018). These four primary characteristics further align with the 10 essential attributes of design thinking (Table 1).

TABLE 1. ESSENTIAL ATTRIBUTES OF DESIGN THINKING

1.	Creativity and innovation
2.	User centeredness and involvement
3.	Problem-solving
4.	Iteration and experimentation
5.	Interdisciplinary collaboration
6.	Ability to visualize
7.	Gestalt view
8.	Abductive reasoning
9.	Tolerance of ambiguity or risk
10.	Blending analysis and intuition

Results from the traditional DoD acquisition organization appear to imply bureaucratic behaviors. The bureaucratic theory was developed by Max Weber in the 1800s and held that rational processes flowing from logic, efficiency, and reason enable efficient leadership power (Jain, 2004). "Bureaucracy is the phenomenon of affirmation of the rationalization of the world" (Paiva, 2014, p. 439) or using a rational calculation to control uncertainty (Serpa & Ferreira, 2019). Further, bureaucratic power comes from specialized knowledge (Serpa & Ferreira, 2019). Three key features identify bureaucratic organizations: formal hierarchical structures, division of labor, explicit and stable rules (Jain, 2004), and a framework where "organizational objectives are not confused with personal motivations" (Serpa & Ferreira, 2019, p. 14). Bureaucratic organizations were found to have seven characteristics as defined in Table 2.

TABLE 2. SEVEN CHARACTERISTICS OF BUREAUCRACY

1.	Hierarchical authority structure	An organization with three or more authority levels and the office is responsible for specific duties (Udy, 1959). Functions are legally defined within written rules (Serpa & Ferreira, 2019).
2.	Specialized administrative staff	A number of personnel of the organization who are "concerned solely with activities other than physical work" (Udy, 1959, p. 793). This staff is responsible for assigning resources, and administration is carried out continually (Udy, 1959). Separation of ownership and employee functions (Serpa & Ferreira, 2019).
3.	Rewards differentiated according to the office	Rewards delineated by the specialized or segmented office (Udy, 1959). Regular wages, income, and career growth are provided over time (Serpa & Ferreira, 2019).
4.	Limited objectives	Organizations and suborganizations have specialized missions, goals, and expertise (Udy, 1959).
5.	Performance emphasis	The amount of award depends on performance, whether quality or quantity (Udy, 1959). Selection and assessment based on technical competence (Serpa & Ferreira, 2019).
6.	Segmental participation	Suborganization participation is based on limited mutual agreement, with known roles and lines of responsibility (Udy, 1959). Formal member relationships are based on the position held (Serpa & Ferreira, 2019).
7.	Compensatory rewards	Higher authorities distribute awards to lower authority members (Udy, 1959).

Bureaucratic behaviors and mindset appear to contribute to DoD's struggle to adopt a disruptive innovation mindset and a broader use of innovation tools. Innovations are less likely to be accepted when they challenge social identity or are seen as potentially deskilling (Lifshitz-Assaf, 2018). The DoD cultivates a particularly conformist social identity in its personnel, who view failure as intolerable (Williams, 2021). To fully consider the phenomenon, it is essential to consider the culture or social norms of the DoD organization.

Researchers have identified organizational conditions (Wrigley et al., 2020) and attributes (Micheli et al., 2019) for design thinking. These conditions and attributes provide insight into the social norms of the high-level behaviors of design-thinking organizations. Furthermore, the social norms of these organizations may be a key element in predicting the success of the

attempts to implement design thinking (Elkins, 2022). To understand better how to implement design-thinking behaviors more widely, it is also crucial to understand the behaviors that currently exist in traditional acquisition organizations, and whether they actually lean to a greater degree toward bureaucratic behaviors. Adaptations of Hofstede's dimensions of culture have provided insights into opposites within segments of the DoD organizational culture based on the mission employed (Sava, 2020). Of note, those on the low side of the scale have a relationship with innovation (Tsegaye et al., 2020), while those on the top side of the scale have a more significant relationship with bureaucracies (Sava, 2020). The latest reform efforts for the DoD acquisition enterprise were directed at dismantling bureaucracy to reach nontraditional vendors using other transaction authorities. The term "nontraditional defense contractors" is precisely defined at 10 U.S.C. § 2302. In practice, they are vendors that do not typically work with the government and that may have a disruptive technology that is potentially advantageous to DoD weapon systems. However, research indicates that organizational factors such as culture are the most cited barrier to innovation (Cinar et al., 2019).

As the DoD works to implement disruptive innovation, culture appears to play a significant role in whether or not change is accepted. Case studies providing insight into organizations that are successfully employing disruptive technology and innovative thinking as their primary mission indicate vital factors contributing to their success (Bonvillian, 2018). Still, what makes these organizations different from traditional acquisition organizations represents a gap in the literature. By better understanding the existing behaviors and culture of these organization types, it may be possible for leaders to understand how to recognize characteristics and effect change as needed. This study investigated the following research question: What perceived differences exist for behaviors of the characteristics of bureaucracy based on organization type (traditional versus technology-enabler organization)?

Research Method

This qualitative comparative research study used an explanatory sequential design to compare the prevailing attitudes, perceived behavioral controls, and social norms related to the characteristics of bureaucracy as behaviors within the two types of organizations. DoD contracting employees were the population for the study, including contracting officers, contract specialists, and procurement analysts. These three types of employees were considered appropriate as the primary makeup of the contracting organization. Due to the natural consistency of work processes within the contracting field, resulting from the heavily regulated nature of the work, these three types of employees provided a consistent framework to analyze and compare behaviors.

The study framework required the similarity of behaviors for validity; as such, the study focused on contracting organizations and excluded specialties from the greater acquisition enterprise. However, an in-depth study of other acquisition fields may be equally valuable for the complete understanding of acquisition limitations for use in future causal research. Direct use of DoD resources was not accessible due to Institutional Review Board constraints. Therefore, participants were solicited using a DoD Facebook professional group, LinkedIn searches with direct messaging, and public membership listings from the National Contract Management Association website. The participants were solicited via mass message and volunteered to participate. While participation was through self-nomination, participants were limited to 10 for each group, and priority was placed on the diversity of responses, including differentiated mission set, organization, and geographical location. Table 3 details the demographic information for interview participants.

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TABLE 3. INTERVIEW PARTICIPANT DEMOGRAPHICS

ID	Years in Field	Role	Service	Single or Multiple Career Fields	Traditional or Technology Enabler	Education	Ethnicity	Gender
1	12	Contracting Officer	Air Force	Single	Technology Enabler	Master's Degree	White	Female
2	13	Procurement Analyst	Air Force	Multiple	Technology Enabler	Doctoral Degree	White	Female
3	22	Contracting Officer	Air Force	Multiple	Technology Enabler	Master's Degree	White	Male
4	7	Contracting Officer	Army	Multiple	Traditional	Master's Degree	White	Male
5	10	Contracting Officer	DoD Agency*	Multiple	Traditional	Master's Degree	White	Male
6	12	Contracting Officer	Air Force	Multiple	Traditional	Master's Degree	White	Female
7	10	Procurement Analyst	Navy	Multiple	Technology Enabler	Master's Degree	White	Male
8	11	Contracting Officer	Air Force	Multiple	Technology Enabler	Master's Degree	White	Female
9	31	Contracting Officer	Air Force	Single	Technology Enabler	Master's Degree	White	Female
10	20	Contracting Officer	Army	Multiple	Technology Enabler	Master's Degree	White	Male
11	7	Contracting Officer	Air Force	Multiple	Technology Enabler	Master's Degree	White	Male
12	20	Contracting Officer	DoD Agency*	Multiple	Traditional	Master's Degree	White	Female
13	8	Contracting Officer	Army	Multiple	Traditional	Master's Degree	Other	Male
14	12	Contracting Officer	Army	Multiple	Traditional	Master's Degree	White	Female
15	2	Contract Specialist	Air Force	Multiple	Traditional	Master's Degree	White	Male
16	7	Procurement Analyst	DoD Agency*	Multiple	Technology Enabler	Master's Degree	White	Male
17	12	Contracting Officer	DoD Agency*	Multiple	Technology Enabler	Master's Degree	White	Male
18	10	Contracting Officer	DoD Agency*	Multiple	Traditional	Master's Degree	Black or African American	Male
19	16	Contracting Officer	Air Force	Multiple	Traditional	Master's Degree	White	Male
20	22	Contracting Officer	Air Force	Single	Traditional	Master's Degree	White	Male

Note. *DoD organizations other than the military services. This roll-up has been used to protect the identity of interview participants in agencies with lower participation numbers.

Qualitative data were collected through interviews using a semistructured measurement tool following the established theory of planned behavior framework designed by Icek Ajzen for measuring the Theory of Planned Behavior elements to predict acceptance of change behavior (Ajzen & Fishbein, 1980). Interview questions were vectored to provide details on the attitudes, perceived behavioral controls, and social norms of the behaviors within contracting organizations. These three elements provided perspective about the thinking of contracting personnel for prediction of acceptance of desired behaviors.

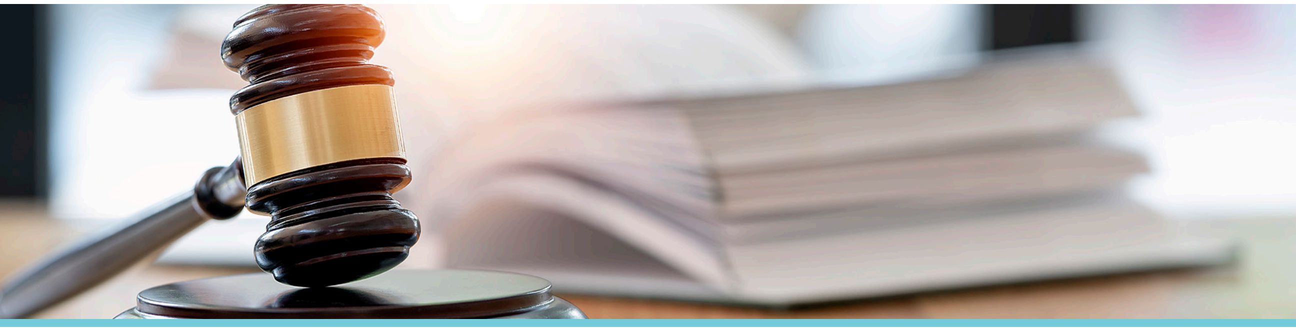
Interview bias for the trustworthiness of data is a concern for qualitative research, as the interview is the only research instrument and may be impacted by the researcher's potential assumptions.

Interview bias for the trustworthiness of data is a concern for qualitative research, as the interview is the only research instrument and may be impacted by the researcher's potential assumptions (Jones & Donmoyer, 2020). This potential bias was mitigated through interview protocols using a semistructured question format, with interviewees leading the substance of the interview without significant borders or constraints to limit the researcher's guidance. Further, direct quotes were selected from participant responses to contextualize emerging themes and ensure the portrayal of participant experiences in their own voice.

Open-ended questions provided an in-depth understanding of the participants' lived experiences, and Zoom was used to record the interviews, which were transcribed into Microsoft Word and then uploaded to NVivo for analysis. The study was conducted over 3 months. During that time, 20 interviews were conducted (10 from each organization type). Participants were encouraged to expand and provide their life experiences for in-depth grounded theory research into the attributes of design thinking and characteristics of bureaucracy. A structured, cascading, three-stage coding method (open, axial, and selective) was used (Edmonds & Kennedy, 2017).

Interviews were first de-identified and loaded into the coding software and labeled with participant numbering. Data were reviewed via open coding for the first round of coding to identify emerging themes via a line-by-line review, identifying 25 themes. Thematic coding was then overlayed with the predefined behaviors or characteristics of bureaucracy. Finally, a third layer of coding was accomplished to align behavioral themes with the framework of the theory of planned behavior for participant attitudes, perceived behavioral controls, and subjective norms surrounding the bureaucracy characteristics.

The data's trustworthiness, validity, and reliability were addressed throughout the research. Interview protocols were used to minimize bias, and participants led the substance of the interview to limit researcher influence over answers (Jones & Donmoyer, 2020). Direct quotes were used to contextualize emerging themes and to render participant experiences in their own voice. Direct quotes were selected based on interesting emerging themes as they appeared and were noted in the text as they were spoken to reduce bias of interpretation. Lincoln and Guba's widely used tenets for establishing trustworthiness in qualitative research were used to ensure trustworthiness: transferability, credibility, dependability, conformability, and authenticity (Elo et al., 2014).



Findings

Research Question: *What behaviors of the characteristics of bureaucracy do employees perceive as prevalent within their organization based on organization type (traditional versus technology-enabler organization)?*

Many themes emerged providing insights into facets of employee attitudes and behaviors. These themes were then layered across the three levels of the organization: leadership, policy activities, and employee. Each theme was analyzed by employee category and type of organization, providing a total frequency of occurrence and a deeper understanding of how these themes emerged across levels of the organization. Frequency totals are provided by organization type for comparison in Table 4.

TABLE 4. CHARACTERISTICS OF BUREAUCRACY BEHAVIOR FREQUENCIES		
Essential Attributes of Design Thinking	**Traditional**	**Technology Enabler**
B1 – Hierarchical Authority Structure	23	7
B2 – Specialized Administration Staffing	50	17
B3 – Limited Objectives	34	8
B4 – Performance Emphasis	22	6
B5 – Compensatory Rewards from Higher to Lower Level	8	3
B6 – Segmental Participation	34	13
B7 – Reward Differentiated According to Organization	10	2

Theme B1. Hierarchical Authority Structure

The characteristic of having a hierarchical structure was a prevalent theme within both technology enablers and traditional organizations. Hierarchical authority structure themes were present within five of the technology-enabler interviews but appeared in all 10 traditional interviews. While the themes were present within both organization types, saturation was far higher in the traditional interviews, with 23 references as opposed to seven for technology-enabler interviews. Two primary themes were prevalent for this characteristic within technology-enabler organizations: a stringent clearance review process and dollar-driven hierarchical reviews.

Hierarchical reviews were noted for the use of U.S.C. § 2371b (renumbered to U.S.C. § 4022) by the five technology enablers identifying this organizational behavior. Congress instituted a very open process allowing for innovation with minimal specifics for the approval process other than a $500 million hierarchical review threshold. However, some agencies appeared to institute rigid lower levels of approval. Two participants also noted that their agencies were more slowly implementing new authorities. For example, Participant 7 noted that headquarters had given broader authority, but "Within my local command, we've had to ratchet down some of the authority." Risk tolerance was identified as a factor for this tightening:

> The leadership has been a little bit more risk-averse, but I do think our current director has been delegating a lot more responsibilities down, which I hope pays dividends in the near future. (Participant 16)

Early adopter technology enablers appeared to present a difference from later adopter technology enablers for this element, with early adopters appearing to have greater latitude for risk and less hierarchy for decision-making. One participant noted this "decision creep" most clearly:

> My answer is gonna change a little bit over time. I will tell you, in 2016, the approval levels were high because, in our organization, it hadn't been done before, and the law was new. Now, that being said, the higher-ups deferred to the lowest level because they didn't know the answer. And that was a great time to be me and to be an agreements officer, because ultimately I had complete authority. The folks that had to approve it didn't know, and they trusted me to go for it, and they were okay with it. And that was 2016; it was a great time. In 2017, as it became more commonplace, then people started to say, you know what, I see dollars are going this direction. It seems like this is a place that I need to play, and I need to start exercising my authority in this zone, and that's when things started to clamp down a little bit, leading up to probably the worst hierarchical structure for approval. (Participant 10)

This theme appeared across the interviews with early technology-enabler participants.

Alternately, the references for hierarchical authority structure were far more saturated and appeared in all 10 interviews with traditional participants, including internal and external hierarchies. References included examples of stovepiping, as shown in the following participant response:

> No, actually, we're gonna retain all the authority here, and we're gonna have nine different entities participating in what could be done by a single person, so it's strange. (Participant 18)

Many noted risk tolerance of leadership as a guiding reason:

> Leadership is a little bit more risk-averse because they'd rather do something that is slower, more bureaucratic, more following the book, go over budget, go slower, but know that they're safer in the end than to go out on a limb, try something that might have a little more risk and a chance of Congress canceling a program. (Participant 12)

However, some participants identified the hierarchy as a positive, implying that this clear authority structure was highly valued in the social identity and culture. One example:

> The approval authorities have changed a lot over the past couple of years, which is a good thing. Like for contracting officers now, we can actually approve up to $25 million before having to go to anybody else. So, there's a lot more that we can handle at our level without having to go chase somebody else down. But even though you have approval of certain things, you still have checks along the way. So, it's not like you're completely on your own. You still have to send things through policy if it's over $10 million, and to legal if it's over $5. And you still have those standard things that have to be met, but you are free to do more by yourself. (Participant 6)

In these cases, the approval levels were seen as a help or comfort level that the process was properly followed, implying that variations to the processes would not be allowable by gatekeepers. Overall, traditional participants appeared to be driven by the hierarchical structure in their reward system and social norms. Most appeared to feel valued for their role in maintaining and helping others to navigate this structure.

Theme B2. Specialized Administrative Staffing

Specialized administrative staffing had the highest saturation level, with 67 references among 10 traditional participants and five technology-enabler participants. Again, saturation was higher among traditional participants, with 50 references compared to 17 among technology-enabler participants. Technology-enabler themes were most present with newer adopters of innovation authorities. Primary themes revolved around the policy review and the standardization of the process.

Technology-enabler participants noted similar issues as traditional participants with "peer review" activities being placed on the award process. One example of this:

Traditional participant responses were heavily saturated with references noting policy group and legal group activities, causing extended schedule delays and adherence to strict processes.

> In 2016, we moved way too fast for policies to be written, and so in 2016 and maybe part of 2017, we did a lot of stuff that didn't have processes in place like that. By 2018, for sure, all those contracting processes had been dropped on top of OTA [Other Transaction Authority], and then it was kind of a battle for how do we get these things back out. (Participant 10)

However, all traditional participants noted a high level of specialized administrative staffing with examples of stringent processes and peer reviews. Traditional participant responses were heavily saturated with references noting policy group and legal group activities, causing extended schedule delays and adherence to strict processes. One example of the rigidness of review functions:

> Personally, I really haven't tried to change processes, not that I haven't wanted to. It really hasn't been appropriate at any time. 'Cause they pretty much are really stuck to the way it's supposed to be. Not a whole lot of give in that area. In our place, I think there would be a lot more if we were our own organization outside of [headquarters location name], but since we fall under [headquarters location name], everything has gotta be just by the book. Because it gets up there and then they'll write you up for everything. (Participant 6)

The implication in this is that any change to the process is incorrect, and there is an incentive to keep things very rigid in the time that one loses in administrative pushback. Another example was provided regarding a minimum of three layers to effect system updates,

> I have done the review, maybe got my leadership to look in the system and concur, and now I've gotta give this form to this other person, a procurement tech. I also think that this missing information is stuff that, if you have eyes, if you have the ability to read English, you can see that these are not the same. And now the procurement tech is gonna verify and type in the characters that you're saying should be there. (Participant 18)

This specialized administrative staffing further extended to very rigid documentation processes for traditional participants. Participants appeared to have some flexibility within the framework but not to change the framework itself, which is a key to design thinking; for example, one participant responded as follows when asked if they were allowed to experiment with different processes or procedures:

> Yes and no. We do have a lot of templates and a lot of processes for the type of work that we do. There is some leeway on some things but not on a lot of others. So, I would say we rely more heavily on the lane of not getting too creative there. (Participant 12)

One technology enabler noted that the FAR allows for differing courses of action, but it requires creativity:

> There was never anything that the FAR kept me from doing ever… I could always find some creative way, using critical thinking, creative thinking of doing it, so it was not ever anything that was policy or regulation, sometimes policy. But nothing in FAR as regulation or the acquisition process stopped me from doing what I needed to do, and often, that would not stop me from getting things done really quickly. I could do OTs [Other Transactions] and FAR contracts pretty much just as quickly. (Participant 9)

On the other hand, traditional participants noted rigidity across the board in the policy review process, reinforced by rigid templated processes, which appeared to reduce the capacity for creative thought, reinforcing bureaucratic organizational characteristics.

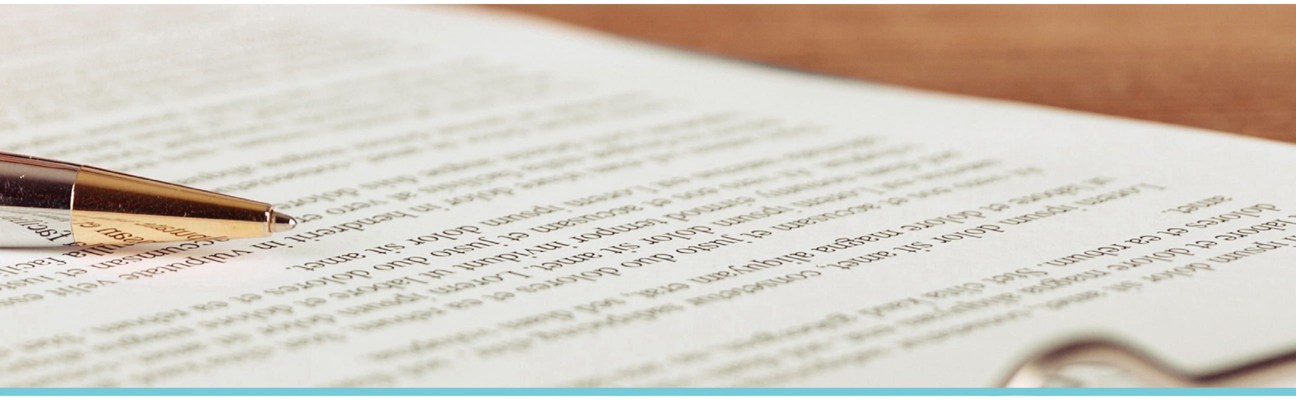
Theme B3. Limited Objectives

Limited objectives had a high saturation level, with 42 references across the whole group. References were again much higher within traditional participants, with 34 references within all 10 traditional participants over

eight references within six of the technology-enabler participants. Limited objectives were a key theme, but the types of responses were significantly different between technology enablers and traditional participants. Two key themes for limited objectives were noted within technology-enabler participants: objectives by mission type and specific limits related to clearance level. Four technology-enabler respondents and two traditional participants noted a separation in their organizations between employees allowed to utilize innovative authorities and those who were not, implying a limitation to creative thought even when the organization leadership recognized the capability to do so. One traditional participant noted a key difference between groups within the same organization:

> We kinda stick to the way it's supposed to be. Now, there is one group. It's called [unit name], and they actually work downtown in the [building name] building. They do IT [Information Technology] work, software innovations, and testing and things, and it's really outside of the normal ways of doing things just because they have program managers and everybody all in the same building, and they're doing rapid work. I don't know. It's just weird the way that it works. I haven't actually been down there, but hearing about it, it's a very fast-moving pace. (Participant 6)

Two key themes for limited objectives were noted within technology-enabler participants: objectives by mission type and specific limits related to clearance level.



These segmented groups were given authority within their unit to use innovation authorities, while others in the same organization were not given the authority for innovation or differentiated procedures.

The secondary theme that emerged for technology enablers in agile classified environments were limitations related to timing of clearances. As a result, participants were, for logistical access reasons, unable to gain the full needed access to an interdisciplinary collaboration that was seen in other groups. One example from Participant 11 noted that clearance issues had resulted in contracting teams being able only to push the paperwork through very specified processes without an understanding of their mission. Technology transfer was further noted as an issue due to organizations' limited objectives and the lack of linkage between program office missions, resulting in a "valley of death," or lack of technology infusion due to the stovepiping of development agencies.

All traditional respondents identified variations of limited objectives. Two themes were prevalent among traditional participants as potential drivers for limited objectives: culture and requirement development. Traditional participants appeared to have a culture of acceptance for "the way it is." This theme appeared in how they viewed their job, with most identifying clear roles with specific duties that were tied to the templates for themselves and their counterparts. Participants noted the need for clean and fully developed requirements documents to engage with new work, implying that contracting professionals did not feel responsible for collaboration of document development. Two examples of this are detailed below:

> [Leadership's] gonna say, submit another PR [Purchase Request]. And so, I think I'd leave it at that. (Participant 15)

> Most of our work is just a paper; it is produced; this is a requirement. They provide us the requirement documentation that we asked for,

Themes for traditional participants evolved around the organization valuing and emphasizing performance by metrics through their rewards programs rather than rewards for more strategic improvements or critical thought.

> and we have kick-off meetings. We have train-the-trainer for source selection, but there is no interaction. (Participant 19)

The rigidity of the process was also detailed as potentially driving limited objectives:

> The hindrance is that folks are conditioned to look for a manual for the answer. It's like, hey, there's not gonna be an answer in the FAR; there's gonna be a rule that you're gonna have to figure out how it applies based on the facts of your circumstance. The hindrance is that people are not prepared to meet the complex situations at all. (Participant 18)

Theme B4. Performance Emphasis

Performance emphasis themes were referenced 28 times across nine traditional and three technology-enabler interviews. Saturation was again higher for this theme within traditional participants, with 22 references, surpassing six references within the technology-enabler interviews. Traditional participant themes had a different focus than technology-enabler themes. Themes for traditional participants evolved around the organization valuing and emphasizing performance by metrics through their rewards programs rather than rewards for more strategic improvements or critical thought. Social norm pressure themes appeared within the interviews as pressure from their customer and their leadership. Note one participant's example of project manager pressure that they had experienced:

> I don't care. Get it done. It needs to be done. Hey, I am a project manager. I need this contract on today. It's not even a requirement. You need it done today. (Participant 4)

Another provided an example of rewards systems and how rewards were driven in their organization.

> So, it's definitely gonna be those urgent requirements. Something like that is gonna get you a reward right away. The commanding officer is

> gonna call up and say, oh no, the [system name] has no satellite airtime this weekend. Those all get rewarded. Typically, it's gonna be those that saved the day. (Participant 5)

Technology enablers differed in themes relating to mission creep and the pressures to maintain performance with changing requirements, but saturation was much lower for the participants in this attribute.

Theme B5. Compensatory Rewards from Higher to Lower

Themes of compensatory rewards from higher to lower level were referenced one time by each of 11 participants across eight traditional and three technology-enabler interviews. Saturation was not significantly high for this theme among those who identified the theme. Themes differed between the two groups. The traditional participants noted compensatory rewards from a higher to lower level, as a matter of fact, and appeared to value this structure. Here is an example:

> My chief of contracting is very big on rewarding people for jobs well done, meaning, depending on the nature of the action, it might be a time off award, it might be a monetary reward, but within [location] and within [organization name], there are agency awards that we have every year that support different things. (Participant 7)

Warrants were also identified as a key reward:

> Warrants were a big thing. The [leader name] would always give those out and because [organization name] [is] right there by [headquarters organization name], the Col and the chief would come down and hand out the warrant. (Participant 13)

Technology-enabler interviews were different in that they noted rewards outside the typical hierarchical reward process, and most noted rewards were intrinsic. Several participants noted the type of work as a reward. For instance,

> I will tell you that I think a lot of people come to the [organization name], and this is government and industry, for the ability to work on interesting problems that help our country. (Participant 17)

> So first of all, people got awesome projects. If you were good, you got put on high-visibility projects. Guess what? You got to create something new that probably no one else has done before, and you can own the process, and that's a reward in and of itself. (Participant 10)

Additionally, several participants noted alternative rewards:

> The other piece that we rewarded folks with was travel. It was, hey, you're the expert. Now, you get to go out to visit DIU-X in Silicon

> Valley, and you're gonna tell them about how you did this opportunity that they're interested in, or you're gonna go down to softworx because they're interested in being trained. Now you're gonna get all these great trips to be an expert. You get to speak publicly. You get to publish things, and that was the big deal for folks. (Participant 10)

Theme B6. Segmental Participation

Segmental participation from higher to lower level themes was highly saturated among both organization types, with references 47 times across 10 traditional and seven technology-enabler interviews. Saturation was higher among traditional participants, with 34 references over 13 in technology-enabler interviews. The segmental nature of the government's official use of multifunctional teams appeared to bring together stovepiped entities over true interdisciplinary collaboration, except for those organizations whose sole mission was of a technology enabler-type organization.

Traditional participants noted complete stoppage when requirements packages were not exact. Additionally, themes emerged of multifunctional team stovepiping. For example,

> We sign agreements, hopefully outlining everybody's responsibilities and roles, that kind of thing. Some programs, I think, probably for the bigger efforts, take it more serious, and so they're gonna actually abide by what you tell them their role is. (Participant 5)

Several noted having to prove themselves to partners over interdisciplinary input. For example,

> I think we oftentimes have to prove ourselves to engineers; we typically have to gain their trust. Those are always the best relationships for me when I can help them get to where they want to go, the correct way, not the [beeline] way that customers always wanna go. (Participant 12)

However, technology enablers did appear to have a more interdisciplinary relationship, describing conversations with field-level users of technology and the need to integrate teams very early. Further, participants noted that they were often able to gain greater access earlier in the process once they had trust from counterparts, but it seemed the trust needed to be earned.

Theme B7. Reward Differentiated According to Organization

Reward differentiated according to organization appeared at lower saturation levels, with 12 references across nine traditional and two technology-enabler interviews. Saturation was higher among traditional participants, with 10 references over two references for technology-enabler interviews; however, themes appeared to be similar to themes identified in the B5 analysis. Responses were referenced as a matter of fact and appeared to be the standard. For example,

> There is an opportunity through the appraisal system and process to reward folks financially, and that is to my understanding of what's taking place and transpiring in this agency. There is nothing in the descriptions of the responsibilities of these employees that relates to coming up with something new that creates efficiencies. There is no incentive to innovate through the system. It is tied to the metrics. (Participant 18)

This was fairly consistent across instances of theme, whether found within traditional or technology-enabler participants.

Implications, Recommendations, and Conclusions

Implications

A stark difference existed between the two populations and a clear alignment of the characteristics of bureaucracy with traditional acquisition organizations. Results indicated a relationship on the low side of the scale for design thinking for traditional participants, denoting congruence with results from Tsegaye's (2020) findings. Traditional participants appeared to have a clear focus as to which portion of the process was their responsibility and only felt accountable for their piece of the process. Further, themes indicated that participants were often unwilling to participate in

front-end activities, as this drove their metrics for compensation higher because it increased their touch time. On the other hand, technology-enabler organizations leaned more significantly toward creativity and gestalt view behaviors. Further, a performance emphasis influenced traditional organization behaviors to a greater degree and occurred within the traditional participants at a rate of four times that found within technology enablers.

Traditional participants were more likely to be focused on a particular part of the process. They were rated on how efficient they were at this piece rather than on their strategic integration within their teams. This separation presented a high saturation level for limited objectives and segmental participation. Participants noted that a strategic suggestion would even be viewed unfavorably in some cases. This difference implies more regimented thinking and rigid processes within traditional communities. Further, there appeared to be significant gatekeeping for this status quo within the culture through the policy groups. Finally, the traditional participants appeared to have a greater compensatory reward motivation than technology enablers, and compensatory rewards were given more for efficiency than for any other reason.

Theme saturation denoted a clear alignment for traditional organizations with interesting insights for technology-enabler organizations for the elements of hierarchical authority and specialized administrative structures. Traditional organizations appeared to have very rigid structures for hierarchy ingrained within the culture. Traditional participants noted these structures and also tended to proclaim them as a more efficient way to work things. This kind of thinking aligns with the original intent of the Theory of Bureaucracy as a rational system of rules reducing redundant thinking for efficiency (Morgan et al., 2019).

Considering the difficulties in implementing innovation when challenging social identity (Lifshitz-Assaf, 2018) and the particularly conforming identity within the DoD (Williams, 2021), an organization that considers bureaucratic processes may have more difficulty relinquishing control of the traditional framework, whether for approvals, responsibilities, or pathways. While these themes were found within segments of technology-enabler organizations, themes indicated a lack of full implementation. Note that top-down methodologies may halt or slow design-thinking implementation, and where the greatest implementation appeared, a higher level of trust seemed to be a factor.

Themes from those implementing the authority as early adopters indicated that a greater level of risk tolerance was accepted. However, as the frequency increased, the traditional processes and approval constraints crept back in. Considering the data from the last couple of years for the use of the other transaction authority, this may partly explain more recent reporting that shows a higher level of use of consortiums and large vendors coupled with a decrease in cost-share levels (McCormick & Sanders, 2022). Consortium awards have allowed for differentiated approaches and enabled more creative output due to reach and industry involvement in forming business relationships. However, the process of awarding for government teams is often standardized and simplified, as evidenced by posted consortia processes (MITRE, 2022). In this way, the government may be outsourcing the thinking of business approach and instituting rigidity into the process when using consortiums rather than innovating business practices.

Recommendations

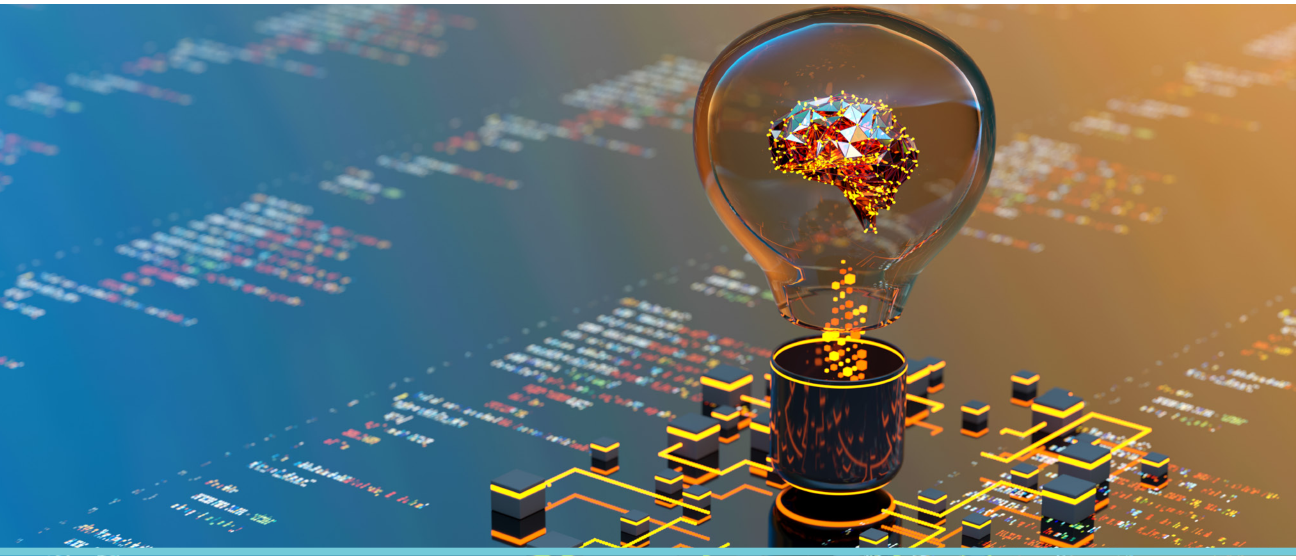
Three recommendations are offered for organizations and managers working to understand better why bureaucracy functions in certain ways within their organization or inhibits business processes within their control.

First, innovation is not something that is singularly aligned with special authorities or outside processes. Those accomplishing some of the study's greatest levels of design thinking were using standard contracts in differentiated ways as alternate authorities (Elkins, 2022). Design thinking requires

Leaders should consider whether the rewards within their system drive the desired process results or strategic results.

greater freedom of movement and a greater level of risk acceptance by those in leadership. This can be accomplished by valuing differentiated thought and risk-taking, and driving a difference of culture into the social identity.

Second, leaders and managers should consider how rigid bureaucratic frameworks might be ingrained and promoted within their processes and the regular compensation reward model. Additionally, employees and leaders may be willing to innovate within the business model, but if policy reviewers or middle supervisors are not, innovation will stall due to incentives. Further, most traditional participant responses appeared to revere those in the community who maintained this structure, indicating a reluctance to veer away from the social identity or norms. Regardless of an employee's willingness to shift, if it is harder to do so by significant levels, the incentives will play against the innovation. Compensation can be a highly effective reward model, but when used within government spheres, there are limitations. The DoD operates on a yearly appraisal cycle, which means that rewards are typically given out once per year via this same appraisal cycle. Traditional participants' rewards were found to be heavily tied to process-oriented behavior and occur annually. At the same time, technology enablers were more intrinsically motivated and driven more regularly through other activities such as travel or conference attendance. In short, rewards can be differentiated and nontraditional, but they must be more immediate and tied to the desired behavior to have the effect of incentivizing. Leaders should consider whether the rewards within their system drive the desired process results or strategic results.



Third, leaders may want to consider how the framing and promotion of bureaucratic behaviors spill over into other areas of contracting. Technology enablers, particularly early adopters of innovation authorities, felt that they had been allotted a certain level of trust to think and mold business relationships. They were aggressively collaborating with stakeholders and molding partnerships that created positive change with a freer hand to think about what hadn't worked in the past and what might work in the future. In contrast, traditional participants primarily felt that there was a "right way to do things." We limit opportunity when we clamp down on this creativity and force pathways. In organizations such as AFWERX, small innovations are being applied to see if they work before scaling, allowing a greater level of controlled trust. This may be a way for managers in these heavily bureaucratic fields to manage risk-taking better.

Conclusions

As the DoD considers how to address new technologies, it should consider that following a traditional model may not get the results needed to win the advantage. A shift to a more risk-acceptance posture with early and aggressive stakeholder collaboration may be necessary to make the needed gains. For instance, in 2021, former Vice Chairman of the Joint Chiefs of Staff General John Hyten identified that China had performed hundreds of hypersonic tests while the United States had accomplished only nine (Clark, 2021). This difference in test methodology implies a stark difference in the model for some of the DoD's most needed technologies. Differentiated business models have the potential as a tool to bridge this divide. This is evidenced in the multiple pathway competitions and divided and integrated development conducted as integrated other transaction authority agreements by Army Futures Command with the Integrated Visual Augmentation System. The DoD should consider whether efficiency is the only goal or whether the goal is to disrupt the field for battlefield advantage.

Innovation tools provide the contracting workforce with alternatives for helping their mission partners move faster and smarter. However, if the teams are not collaborating until the requirement is fully solidified, typically only one path remains available to meet "need by" dates. Today, risk acceptance and more aggressive approaches in reducing barriers, reaching industry, and rethinking the way that we do business are key to gaining the edge. These approaches require aggressive stakeholder collaboration before the requirement is formed, which means that the contracting workforce is a critical partner to enablin the support network of technology enablers.

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Author Biography

DR. JENNIFER W. ELKINS

is a Senior Procurement Analyst and Procurement Portfolio Manager for the National Aeronautics and Space Administration (NASA) and leads oversight and execution of a $150 billion procurement portfolio. She has 22 years of military and civilian service in contracting, program management, and programming and budgeting activities. Her research interests include design thinking and organizational behavior and culture in the innovation space.

(E-mail address: jenniferwelkins@gmail.com)


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Featured Book

***Logistics: Principles and Applications* (Second Edition)**

Author: John W. Langford

Publisher: McGraw-Hill (SOLE Press)

Copyright Date: 2007

Hard/Softcover/Digital: Hardcover, 570 pages

ISBN-13: 9780071472241

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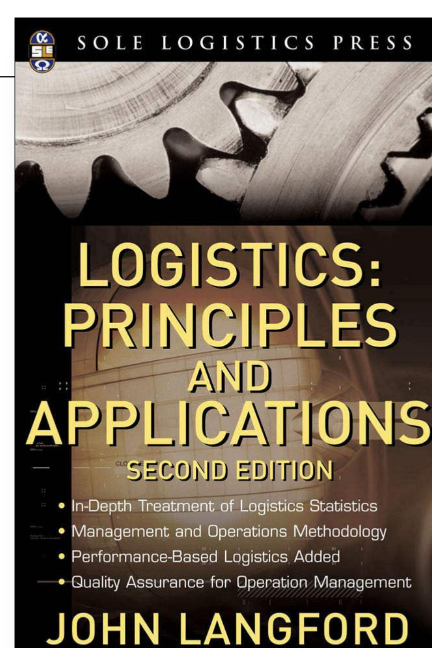
Reviewed by: Shawn Harrison



Review:
While in print for over a quarter century, J. W. Langford's *Logistics: Principles and Applications* remains a valuable desk reference for the acquisition workforce. In the author's own words, he designed the text as a resource for college students, technicians, and "other professionals who seek an appreciation of the basic principles and applications of logistics." In addition, as part of the International Society of Logistics Engineers (SOLE) press series, this book also serves as a seminal reference for preparing for the society's Certified Professional Logistician (CPL) exam. For the acquisition professional, this desk reference is a well-crafted compendium for diving into the technical details of life-cycle logistics and systems engineering functional areas. More broadly, its coverage of diverse topics will also be of interest to program managers, business and financial managers, cost estimators, contracting specialists, and test and evaluation professionals.

Although replete with charts and formulas, the text is surprisingly readable, and thanks to a well-organized table of contents and index, readers can quickly find specific topic(s) of interest. Langford offers a thorough treatment of the 12 DoD Integrated Product Support (IPS) Elements (minus Training and Training Support and Product Support Management, and with some "legacy terminology"). He also covers statistics, reliability and maintainability (R&M), availability, quality assurance, human factors engineering, safety engineering, contracting, critical-path schedule analysis, work breakdown structure, learning curve, financial analysis, depreciation, life-cycle costs, performance-based systems engineering, logistics support analysis (supportability analysis), and configuration management.

Langford's text serves as a time-tested resource for weapon system design, development, testing, and fielding. His chart demonstrating that 60% of life-cycle costs (LCC) occur during Operations and Support and 85% of LCC are determined by Milestone B, serves as a reminder of the need for acquisition professionals to focus on product support early in design. While built upon what is now DoD Instruction 5000.02 Operation of the Adaptive Acquisition Framework, the text informs work on other pathways as well. Acquisition practitioners will find useful chapters for many life-cycle management activities, including: calculating predicted R&M results; formulating a sampling construct for a Quality Assurance Surveillance Plan; developing and interpreting contract geometry for incentive-type contracts; and analyzing schedule networks for critical path(s) and risks. Still others include assessing manufacturing and production learning curves; calculating net present value and return on investment; specific principles and best practices for most of the Integrated Product Support Elements, such as supply demand forecasting (including economic order quantity and sparing); and supportability analyses. The addition of a performance-based systems engineering chapter is a welcome update to inform practitioners regarding incentivizing achievement of key performance parameters leading to more affordable sustainment outcomes. Unfortunately, the new chapter displaced a very useful chapter in earlier editions on design reviews and audits, which, like the cancellation of MIL-STD-1521B, Technical Reviews and Audits for Systems, Equipments, and Computer Software, has "passed into acquisition legend." Finally, the relatively few sections (e.g., those related to software development, the DoD acquisition framework, etc.) that are somewhat outdated in today's acquisition environment do not significantly detract from this highly useful and relevant text.

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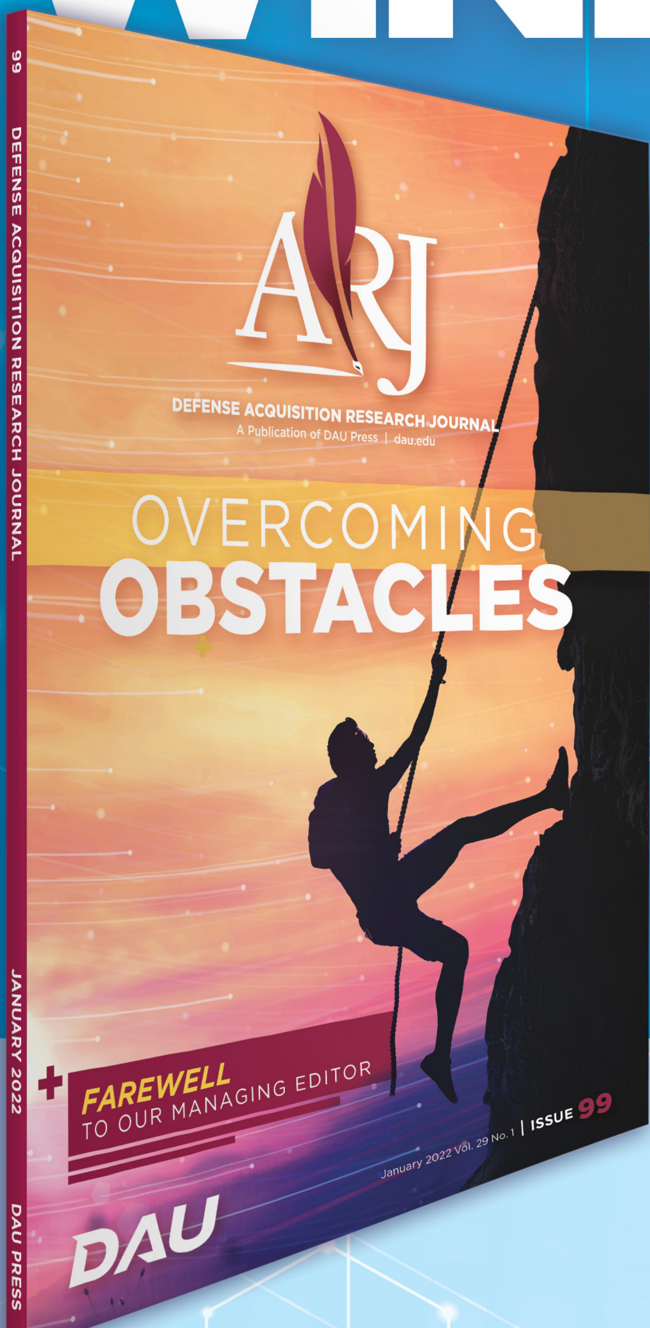

Nina Austin, Emily Beliles, Nicole Brate, and Christopher McGowan

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Trusting AI: Integrating Artificial Intelligence into the Army's Professional Expert Knowledge

C. Anthony Pfaff, Christopher J. Lowrance, Bre M. Washburn, and Brett A. Carey

Summary:

This study is the result of 2 years of observing the XVIII Airborne Corps Scarlet Dragon exercises, which include Project Ridgway, a bottom-up effort to test artificial intelligence (AI) and data technologies and integrate them with legacy targeting processes and systems. During an early iteration of Scarlet Dragon in 2020, then XVIII Airborne Corps Commander Lt Gen Michael "Erik" Kurilla rhetorically asked, "How do I trust this system?" To address the challenge of increasing AI and data literacy in the military, this study explores the problem of trust by asking what military professionals need to know to integrate AI and data technologies into the acquisition profession's body of expert knowledge.

APA Citation:

Pfaff, C. A., Lowrance, C. J., Washburn, B. M., & Carey, B. A. (2023). *Trusting AI: Integrating artificial intelligence into the Army's professional expert knowledge.* U.S. Army War College Press. https://press.armywarcollege.edu/monographs/959/

Application of an Artificial Intelligence-Enabled Real-Time Wargaming System for Naval Tactical Operations

Rachel S. Badalyan, Andrew D. Graham, Michael W. Nixt, and Jor-El Sanchez

Summary:

The Navy is taking advantage of advances in computational technologies and data analytic methods to automate and enhance tactical decisions to support Warfighters in highly complex combat environments. Novel automated techniques offer opportunities for tactical Warfighter support through enhanced situational awareness, automated reasoning and problem-solving, and faster decision timelines. This capstone project investigated the use of AI and game theory to develop real-time wargaming capabilities to enhance Warfighters' ability to explore and evaluate the possible consequences of different tactical courses of action to improve tactical missions.

APA Citation:

Badalyan, R. S., Graham, A. D., Nixt, M. W., & Sanchez, J. (2022). *Application of an artificial intelligence-enabled real-time wargaming system for naval tactical operations* [Master's thesis, Naval Postgraduate School]. The NPS Institutional Archive. https://calhoun.nps.edu/bitstream/handle/10945/70624/22Jun_Badalyan_et_al.pdf?sequence=1&isAllowed=y

Artificial Intelligence for Wargaming and Modeling

Paul K. Davis and Paul Bracken

Summary:

In this paper, the researchers discuss how AI could be used in political-military modeling, simulation, and wargaming of conflicts with nations having weapons of mass destruction and other high-end capabilities involving space, cyberspace, and long-range precision weapons. AI should help participants in wargames, and agents in simulations, to understand possible perspectives, perceptions, and calculations of adversaries who are operating with uncertainties and misimpressions. The content of AI should recognize the risks of escalation leading to catastrophe with no winner, but also the possibility of outcomes with meaningful winners and losers. The researchers examine implications for the design and development of families of models,

simulations, and wargames using several types of AI functionality. They also discuss decision aids for wargaming, with and without AI, informed by theory and exploratory work using simulation, history, and earlier wargaming.

APA Citation:

Davis, P. K., & Bracken, P. (2022). Artificial intelligence for wargaming and modeling. *Journal of Defense Modeling and Simulation,* 1–16. https://www.rand.org/content/dam/rand/pubs/external_publications/EP60000/EP68860/RAND_EP68860.pdf

Artificial Intelligence and Human Interaction: How to Keep the Human in the Loop

Ashley N. Gizas, Benjamin R. Hill, Megan Meisner, Dawn P. Patterson, and Nicole Wilson

Summary:

The researchers use data from the System for Award Management (SAM) along with discussions from subject-matter experts, both in government and industry, to capture how AI-enabled systems are currently being procured by the Army. The combined results of the team's methodology revealed that understandings vary across the Army of what an AI requirement is, and no obvious processes or specific AI acquisition guidelines are universally followed when developing an AI requirement. It was also apparent that Human Systems Integration (HSI) was not always included in requirements as required by Army regulations. This disparity appeared to have three major root causes: immaturity of DoD Army guidance, shortcomings in AI-related training for acquisition personnel, and negligence surrounding the incorporation of HSI elements into Army requirements.

APA Citation:

Gizas, A. N., Hill, B. R., Meisner, M., Patterson, D. P., & Wilson, N. (2022). *Artificial intelligence and human interaction: How to keep the human in the loop* [Master's thesis, Naval Postgraduate School]. The NPS Institutional Archive. https://calhoun.nps.edu/bitstream/handle/10945/71133/22Sep_Gizas%20et%20al.pdf?sequence=1&isAllowed=y

Artificial Intelligence: Status of Developing and Acquiring Capabilities for Weapon Systems

Jon Ludwigson and Candice N. Wright

Summary:

DoD reports that AI is poised to change future battlefields and the pace of threats from U.S. adversaries. AI capabilities could enable machines to perform tasks that usually require human intelligence, such as identifying potential threats or targets on the battlefield. DoD designated AI a top modernization area and is investing heavily in AI tools and capabilities. Other nations are making significant investments in this area that threaten to erode the U.S. military technological and operational advantage. This report examines (a) the unique nature of AI and current status of AI capabilities that support weapon systems; and (b) how DoD is addressing challenges in developing, acquiring, and deploying AI capabilities for weapon systems.

APA Citation:

Ludwigson, J., & Wright, C. N. (2022). *Artificial intelligence: Status of developing and acquiring capabilities for weapon systems* (Report No. GAO-22-104765). https://www.gao.gov/assets/gao-22-104765.pdf

Operational Feasibility of Adversarial Attacks Against Artificial Intelligence

Li Ang Zhang, Gavin S. Hartnett, Jair Aguirre, Andrew J. Lohn, Inez Khan, Marissa Herron, and Caolionn O'Connell

Summary:

A large body of academic literature describes myriad attack vectors and suggests that most of the DoD's AI systems are in constant peril. However, RAND researchers investigated adversarial attacks designed to hide objects (causing algorithmic false negatives) and found that many attacks are operationally infeasible to design and deploy because of high knowledge requirements and impractical attack vectors. As the researchers discuss in this report, tried-and-true nonadversarial techniques can be less expensive, more practical, and often more effective. Thus, adversarial attacks against AI pose less risk to DoD applications than academic research currently implies. Nevertheless, well-designed AI systems as well as mitigation strategies can further weaken the risks of such attacks.

APA Citation:

Zhang, L. A., Hartnett, G. S., Aguirre, J., Lohn, A. J., Khan, I., Herron, M., & O'Connell, C. (2022). *Operational feasibility of adversarial attacks against artificial intelligence.* RAND. https://www.rand.org/content/dam/rand/pubs/research_reports/RRA800/RRA866-1/RAND_RRA866-1.pdf

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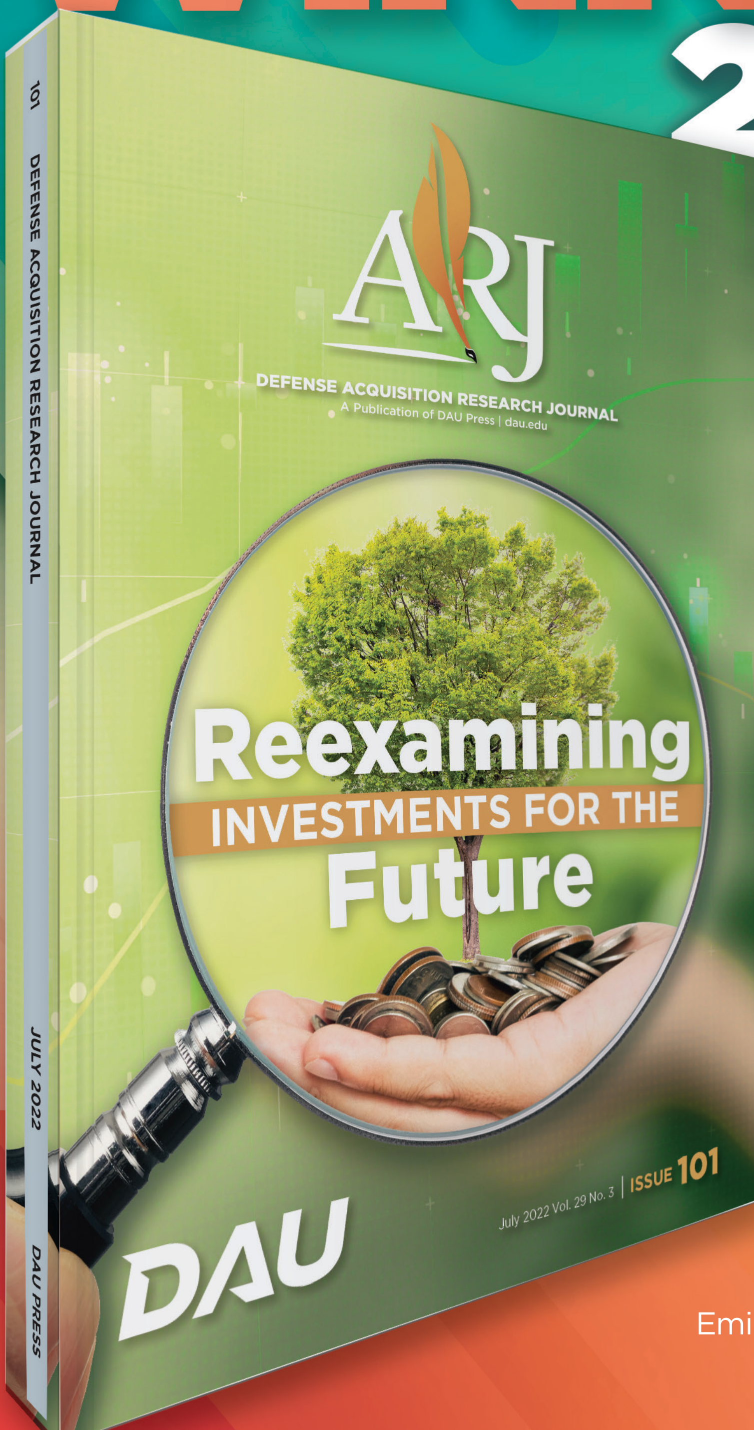

Norene Johnson,
Emily Beliles, and Nicole Brate

DAU Press

Fort Belvoir, VA

Defense ARJ Guidelines FOR CONTRIBUTORS

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- Situation/problem
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- Conclusions
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Prospective authors may direct their questions to the *Defense ARJ* Managing Editor at DefenseARJ@dau.edu or by calling 703-805-5126 or at the address below.

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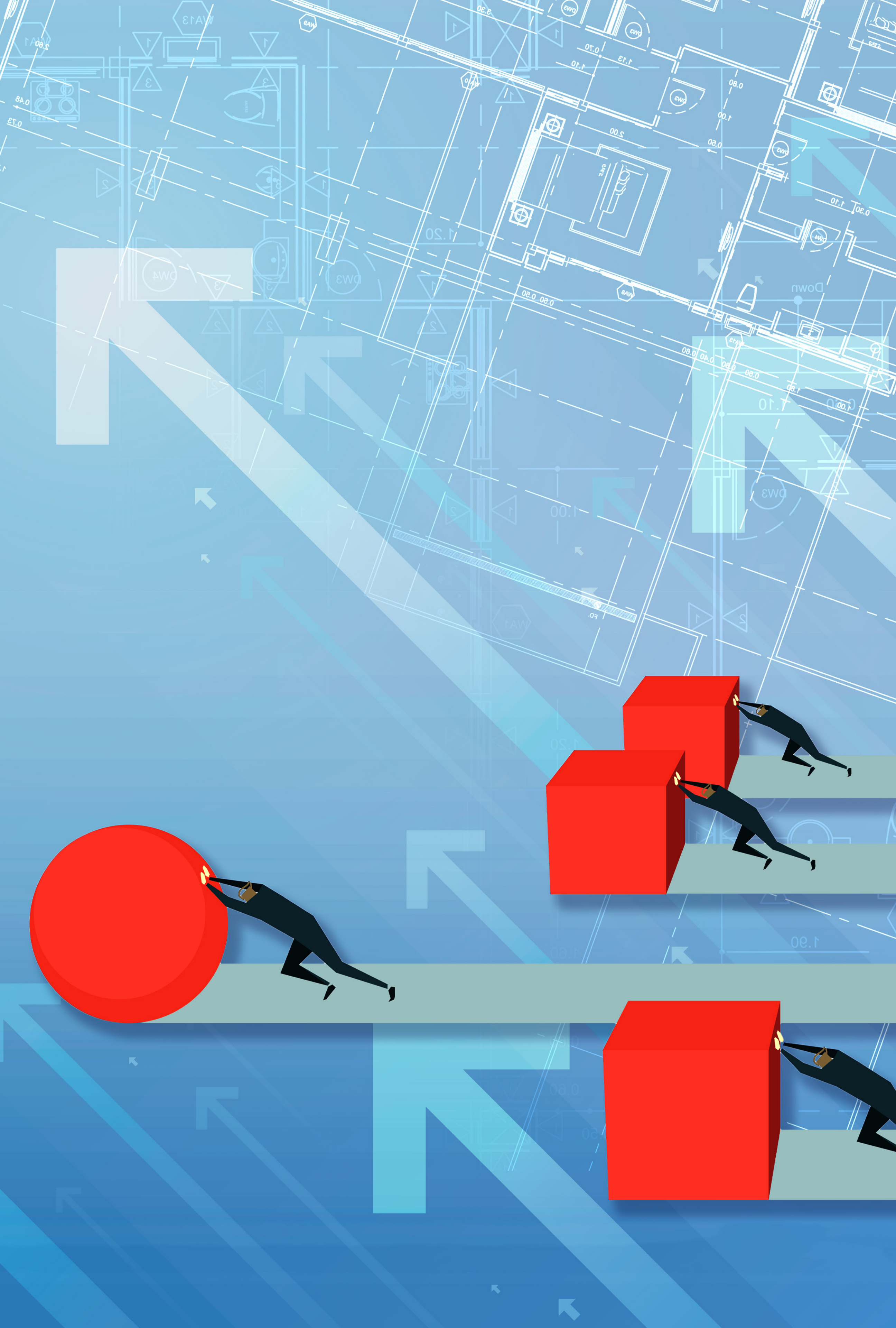

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