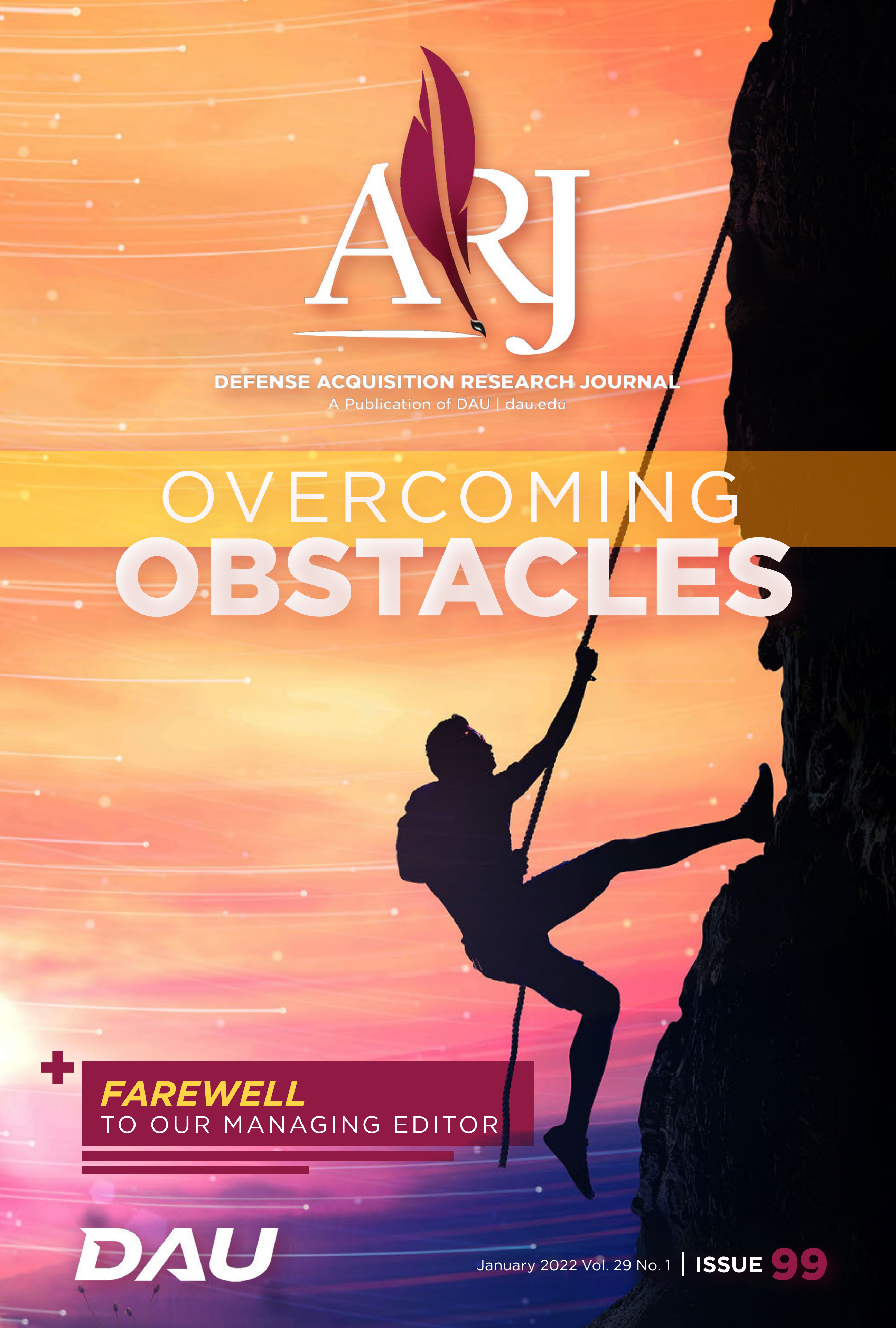

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+ **FAREWELL** TO OUR MANAGING EDITOR

DAU

January 2022 Vol. 29 No. 1 | ISSUE 99

ARTICLE LIST

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DAU

ISSN 2156-8391 (print) and ISSN 2156-8405 (online)
DOI: https://doi.org/10.22594/dau.012022-99.29.01

The *Defense Acquisition Research Journal*, formerly the *Defense Acquisition Review Journal*, is published quarterly by the DAU Press and is an official publication of the Department of Defense. Postage is paid at the U.S. Postal facility, Fort Belvoir, VA, and at additional U.S. Postal facilities. Postmaster, send address changes to: Editor, *Defense Acquisition Research Journal*, DAU Press, 9820 Belvoir Road, Suite 3, Fort Belvoir, VA 22060-5565. The journal-level DOI is: https://doi.org/10.22594/dauARJ.issn.2156-8391. Some photos appearing in this publication may be digitally enhanced.

DEFENSE ACQUISITION RESEARCH JOURNAL
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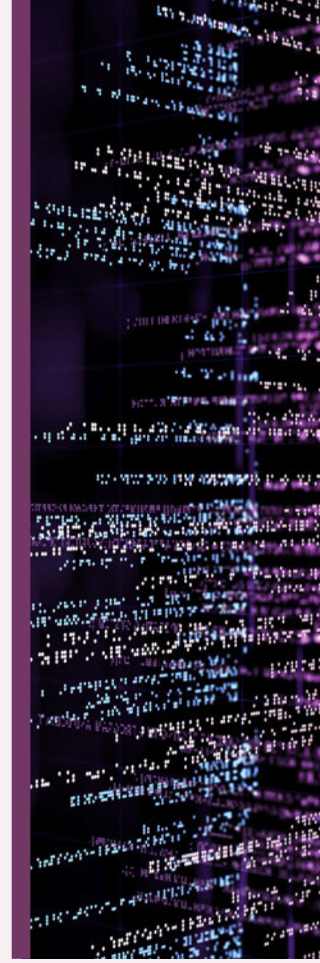

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Optimal Talent Management of the Acquisition Workforce in Response to COVID-19: Dynamic Programming Approach

Tom Ahn and Amilcar A. Menichini

The authors forecast the long-run retention behavior of the Defense Acquisition Workforce using a dynamic programming approach. Their findings posit that employees are hesitant to leave the DoD while the civilian economy is in flux; however, once recovery is well underway, acquisition workers rapidly exit, potentially leading to a deficit of experienced employees.

CONTENTS | Featured Research

FROM THE CHAIRMAN AND EXECUTIVE EDITOR

Dr. Larrie D. Ferreiro

The theme for this issue is "Overcoming Obstacles." Our current acquisition environment presents unique challenges on many fronts, several of which are identified in this issue relating to cost growth models, DevOps, and COVID-19. Each of these articles outlines keys to aid the acquisition workforce in overcoming these obstacles and maintaining our relevance in a rapidly changing environment.

The first article, by David L. McNicol, asks, "Can We Explain Cost Growth in Major Defense Acquisition Programs?" McNicol highlights the lack of a good model to explain the causes of cost growth and identifies some of the implications of this on defense acquisition policy.

In the second article, "Challenges of Adopting DevOps for Combat Systems Development Environment," the authors, Andrew W. Miller, Ronald E. Giachetti, and Douglas L. Van Bossuyt, interviewed multiple subject matter experts in the Navy and DoD to identify some of the challenges and obstacles to adapting DevOps to the Navy acquisition process.

Authors Tom Ahn and Amilcar A. Menichini examine the effect of the pandemic on DoD worker retention rates in their article, "Optimal Talent Management of the Acquisition Workforce in Response to COVID-19: Dynamic Programming Approach." The results of their research highlight ways that the DoD can take advantage of negative impacts to the civilian labor market in the short term as well as reforms that need to be made to retain high-quality DoD workers long term.

This issue's Current Research Resources in Defense Acquisition focuses on Public Procurement and COVID-19. This section highlights research on the effects of COVID-19 on federal contracting and positive ways that the DoD can respond to this unique obstacle.

The featured work in the Defense Acquisition Reading List book review is *Logistics Engineering and Management* by Benjamin S. Blanchard, reviewed by Shawn Harrison.

Sharp-eyed readers will notice a few updates to our January issue. With the new year, our graphic designer, Nicole Brate, has brought a fresh new look to articles in both our print and online editions. We encourage you to check out our online issue for some exclusive online content. Readers will also notice that this is issue #99. Our next issue, #100 (April 2022) will celebrate the centenary of this journal, with a "best-of" selection of articles that have impacted the Defense Acquisition Workforce over the past quarter-century.

Dr. Richard Shipe has left the Editorial Board. We thank him for his service.

We announce another major change in the masthead. We are celebrating a generation of service from our outgoing Managing Editor, Norene Johnson, and 27 years with the *Defense Acquisition Research Journal* and its predecessors. Norene has been on the Journal staff in various capacities since the publication launched in 1994. She was primarily responsible for its evolution from a black and white publication printed on recycled paper to the full-color periodical we enjoy today. Norene started out as the editorial assistant, was then promoted to editor, and eventually became the Managing Editor in the mid-2000s. Under her leadership, the Journal has won numerous awards for publication excellence on the national and international level. Although she is no longer the Managing Editor, she will still be involved indirectly as the Chief of Visual Arts and Press.

At the same time, we are proud to announce that Emily Beliles will be taking over the Managing Editor position. Emily has had the opportunity to work with many reviewers and authors in her role as Assistant Editor for the past 5 years (and to be clear, is the co-author of this issue's Remarks). She and all of us at the *Defense ARJ* look forward to a continued commitment to award-winning quality and cutting-edge research in support of the Defense Acquisition Workforce in 2022 and beyond.

MARCOM AWARD FOR PRINT MEDIA | ACADEMIC RESEARCH JOURNAL

WINNER 2021

Norene Johnson, Emily Beliles, and Nicole Brate

DAU Press

Fort Belvoir, VA

TURNING OVER THE REINS

Of my 35 years of Federal service, I have spent the last 27 as a member of the *Defense Acquisition Research Journal* processing and production team. I was fortunate to be there when the publication rolled off the press for the very first time as the *Acquisition Review Journal* (1994). I was also there for two name changes: *Defense Acquisition Review Journal* (2004) and *Defense Acquisition Research Journal* (2011–Present). Over the years, I have enjoyed working with the staff, authors, and subject matter experts. Therefore, with sadness and excitement, it is time for me to pass the reins of the publication over to Ms. Emily Beliles, the new managing editor of the *Defense ARJ*. She has served as the assistant editor for 5 years and has definitely made her mark in the advancement of this multi-award winning publication. Now, she is going to take the publication to the next level, leading the charge to enhance the digital presence of the journal on the DAU website and social media platforms. Although I will no longer serve as managing editor, I will provide oversight as Chief, DAU Visual Arts and Press. Thank you in advance for your continued support. The *Defense Acquisition Research Journal* is truly a publication of excellence.

Several members of our Editorial Board sent the following messages of thanks to Norene for her work at the *Defense ARJ*.

Congratulations to Norene for a stellar, long term track record and to Emily for taking on the reins from here!

- DR. MARINA THEODOTOU

On behalf of DAU Midwest, I'd like to take this opportunity to say thank you, Norene, for helping us reach the customer with excellent information, stories, and opportunities to improve Acquisition outcomes across the Defense Acquisition Workforce! Your leadership and dedication are appreciated!

- JERRY VANDEWIELE

After 27 years of your wonderful leadership, the [*Defense*] *Acquisition Research Journal* reflects your energy and determination to share knowledge. The quality and quantity of the Journal's science-based research is quite a legacy. On behalf of your colleagues, friends, and learners at the Defense Systems Management College, thank you! We are all looking forward to the "next edition" in your DAU career.

- DR. DAVID L. GALLOP

Very impressive! And obviously, the Journal is in good hands. Congratulations!

- DR. STEVEN A. FASKO

Norene it has been my pleasure to work with someone as professional and knowledgeable as you. I wish you the very best in future endeavors.

- DR. DANA STEWART

DAU CENTER FOR DEFENSE ACQUISITION

RESEARCH AGENDA 2022

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 cancelled. 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, for example, percentage of revenue devoted to IR&D, 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 has been the impact of IR&D on developing 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, is there evidence that sole source can result in lower overall administrative costs at both the government and industry levels, to the effect of lowering total costs?
- What are 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 are there (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 resulted in actual change in 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 institution 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 system 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 (ATO) construct for all software-centric acquisition programs?
- How can we articulate cyber risk versus operational risk so Combatant Commands (COCOMs) 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 services 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 the pass-through costs?
- For Base Operations and Support (BOS) contracts, is there 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 whether the small business 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 service 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 service 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.) of these contracts?

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 return on investment (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 if 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)

Potential authors are encouraged to peruse the DAU Research website (***https://www.dau.edu/library/research/p/Research-Areas***) for information.

We're on the Web at:
http://www.dau.edu/library/arj

ISSUE 99
JANUARY 2022
VOL. 29 NO. 1

Image designed by Nicole Brate

CAN WE EXPLAIN COST GROWTH IN MAJOR DEFENSE ACQUISITION PROGRAMS?

David L. McNicol

The question asked in this article is whether the shared intellectual property of the acquisition community includes an adequate theory of cost growth in major defense acquisition programs (MDAPs). This question is given concrete form by cost growth data for 123 MDAPs. These data are grouped into categories, which range from very small—negative, in fact—cost growth to cost growth in excess of 100%. Potential explanations for this broad range of cost growth considered are: the conventional wisdom about cost growth; a recent RAND study that closely examined cases at both ends of the distribution, along with some possible extensions of that study; and a recent model of the root causes of cost growth. The author argues that each of these falls short; in particular, it seems that the defense acquisition community at large does not have a good explanation of cost growth in the broad range of 30% to 100%.

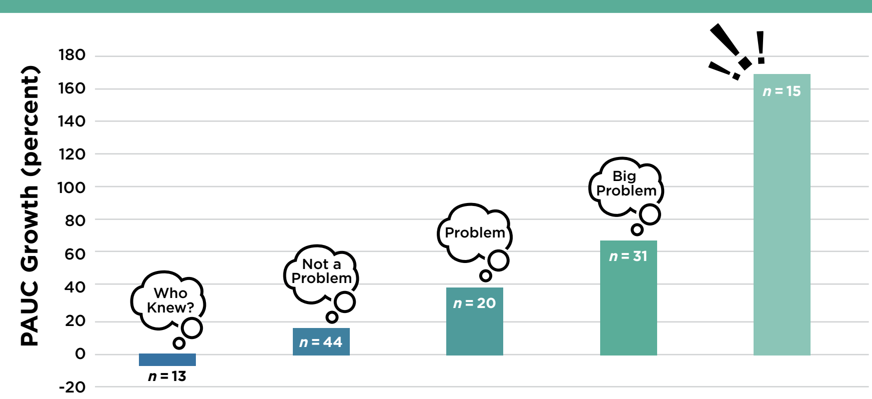
DOI: https://doi.org/10.22594/dau.21-867.29.01
Keywords: *Cost Growth, Major Defense Acquisition Programs, Acquisition Policy, Incentives*

This article examines whether the shared intellectual property of the acquisition community includes an adequate theory of cost growth in major defense acquisition programs (MDAPs), and—having concluded that it does not—characterizes the largest gap in our collective understanding of MDAP cost growth. The term "shared intellectual property" is used to mean an understanding that is possessed to an important extent by the experienced members of the Department of Defense (DoD) acquisition community.

Three alternative explanations of cost growth are examined. The first of these is the author's understanding, based on decades of experience, of the acquisition community's conventional wisdom about cost growth. The second is the widespread belief that the proximate cause of the largest part of cost growth in MDAPs is due to unrealistic elements included in Milestone (MS) B baselines. Over the years, this idea has been explored by several major studies, most recently a 2017 RAND study by Lorell et al. (2017). The third, and by far least well known, is a theory of the root causes of cost growth proposed by McNicol (2020).

The exam question used to test these theories is novel: Does the theory provide a plausible explanation of the full range of cost growth observed, from the very small—negative, in fact—to the very large. The means used to test how well an idea explains the data varies from one case to the next.

FIGURE 1. RANGE OF COST GROWTH DATA



Note. The data in this figure are for 123 MDAPs that passed Milestone (MS) B during the bust funding climates Fiscal Year (FY) 1965–FY 1980 and FY 1987–FY 2002. In these climates, competition among MDAPs for funding was particularly intense. Programs that passed MS B in boom climates are set aside initially. The measure of cost used is Program Acquisition Unit Cost (PAUC) in program base-year dollars. Cost growth is the ratio of actual PAUC observed at the end of the acquisition cycle adjusted to the MS B base-line quantity procured divided by MS B PAUC.

The average quantity adjusted PAUC growth and number of observations by category are Category I: -8% (13); Category IIa: 15% (44); Category IIb: 39% (20); Category IIc: 68% (31); Category III: 171% (15).

The Data

Figure 1 displays the cost growth data used, grouped into five categories of average cost growth:

- Category I: MDAPs with negative unit cost growth—that is, for which, when the acquisition was completed, unit cost, adjusted to the Milestone (MS) B quantity, was less than had been projected at MS B.
- Category II: MDAPs that had cost growth between zero and 100%. This category is divided into three subcategories:
    a. Cost growth of less than 30%
    b. Cost growth of 30% to 50%
    c. Cost growth of more than 50% but no more than 100%
- Category III: Cost growth of more than 100%

The observations are based on the cost estimates in the programs' MS B baselines. These distinguish development, procurement, and military construction, and generally follow the lines of the program work breakdown structure currently provided by DoD Military Standard 881E. The individual supervising the estimate decides how many levels down into the structure to go. Typically, the Office of the Secretary of Defense (OSD)-level independent cost estimate is made at a relatively high level and will be composed from, say, 10 to 50 distinct cost categories. An estimate is made for each of these categories, covering the program's entire acquisition cycle. The estimates made by program offices often are considerably more detailed.

This article uses the only publicly available database with cost growth data for a substantial number of MDAPs. The database includes at least some data on all MDAPs that entered what is now called Engineering and Manufacturing Development (EMD) during the period Fiscal Year (FY) 1965–FY 2009. DoD offices and specific parts of the DoD Decision Support System process are referred to by the names that were commonly used for them during FY 2000–FY 2009. Cost growth data are included in the database for 123 MDAPs that passed MS B during one

of two "bust" periods, when competition for acquisition funding was relatively intense (FY 1965–FY 1980 and FY 1987–FY 2002). Omission of MDAPs that passed MS B during boom periods (FY 1981–FY 1986 and FY 2003–FY 2009) removes a complication: the very large difference in average Program Acquisition Unit Cost (PAUC) growth between MDAPs that passed MS B in bust periods and those that passed MS B in boom periods. (On the association of funding climate and cost growth, see McNicol and Wu [2014] and McNicol [2018].) This problem is too large to include within the scope of this article. Omitting the 62 MDAPs that passed MS B in boom periods does not, however, eliminate the problem illustrated in Figure 1: It is still reasonable to ask whether current conceptions can explain the full range of cost growth presented by 123 MDAPs that passed MS B in bust periods.

The cost growth figures used are based on PAUC. Acquisition cost is the sum of Research, Development, Test, and Evaluation (RDT&E) cost; procurement cost, that is, the cost of buying units once they are developed; and system-specific military construction costs. PAUC is the ratio of acquisition cost to units acquired. The denominator of PAUC growth is the PAUC in the MS B baseline (in program base-year dollars). The numerator is the PAUC reported in the program's final Selected Acquisition Report (SAR) (also in program base-year dollars), adjusted to the MS B baseline quantity by moving quantity acquired up or down the cost progress curve, as appropriate. This adjustment removes changes in quantity acquired as a factor that needs to be considered. The resulting cost growth figures are estimates of what cost growth would have been had the MS B baseline quantity been acquired. Of the 123 MDAPs in the sample, 110 were completed by the end of FY 2016. Actual PAUC was known for these programs; for the other 13, the 2016 SARs include forecasts of the acquisition costs of the program when completed.

Conventional Wisdom and the Data

The initial impulse of someone who approaches Figure 1 in terms of the conventional wisdom probably is to question the data. It is mainly the 13 MDAPs (all of which were completed by FY 2016) with negative cost growth that trigger this response. A comment often heard is that "all major acquisition programs" show cost growth. They do not. Virtually all programs do show growth in RDT&E cost at the contract level during the Technology Maturation and Risk Reduction phase that precedes EMD. Further, most (but not all) programs show growth in RDT&E for the EMD phase. This does not imply, however, growth in acquisition costs. In the author's experience, procurement characteristically accounts for 70% to 80% of acquisition cost, and in some cases, procurement cost declines by enough to yield a quantity-adjusted PAUC growth that is negative.

Once the shock of Figure 1 has worn off, further discussion probably would tacitly assume that MDAPs increased in cost over time and offer reasons for this presumed increase. Examples of such reasons often heard are increased use of advanced technologies, more programs that are systems of systems, and greater use of software. An explanation of Figure 1 in these terms would be that the higher cost growth systems tend to be the more recent MDAPs and/or those with problematic program features. A look at the data is enough to call such an explanation into question. The earliest of the MDAPs in Category III is the M-60 A2 Patton tank, which entered EMD about 1965, and the median program in Category III entered EMD in 1987. While Category III includes programs of each of the Services, Army programs are significantly overrepresented (11 of 15), which may reflect unique aspects of Army policy.

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More generally, the conventional wisdom conflates two distinct assertions—one accurate and one not. The preponderance of evidence supports the conclusion that average unit acquisition costs at completion of successive generations of particular system types (destroyers, for example) have increased over time (Arena et al., 2006a, 2008). However, average PAUC growth of annual cohorts of MDAPs has shown no persistent tendency to increase over time (Arena, 2006b).

Finally, conventional wisdom tends to ignore the MS B review. A MS B review involves examinations of the proposed program by Service and OSD staff elements, and each MS B baseline is approved by a senior DoD official. It is the nominal intent of the MS B review to ensure that, at that stage, the MDAP conforms to DoD acquisition policy, which provides that the elements of the baseline, including the cost estimate, should be realistic. Consequently, substantial cost growth in an MDAP necessarily involves some degree of policy or institutional failure.

2017 RAND Study

Lorell et al. (2017) is the culmination of several studies undertaken at RAND. It differs from other case studies in that it is a comparative examination of cost growth in six MDAPs with extremely high growth and four with very low growth. Such a comparison is important because some program characteristics associated with cost growth are common. Most MDAPs, for example, have some degree of concurrency between EMD and procurement, and critical technologies that are to some degree immature at MS B.

Lorell et al. (2017) find that programs with extremely high-cost growth each possessed all or nearly all of five characteristics:

1. Immature technology; integration complexity
2. Unclear, unstable, or unrealistic requirements
3. Unrealistic cost estimates
4. Acquisition strategy and program structure not tailored for level of risk
5. MS B and MS C approved at the same time

These characteristics were found to be entirely absent in two of the low-cost growth programs, and the remaining two programs possessed, respectively, one and two of the five factors that cause extremely high-cost growth. So, to the extent that Lorell et al. (2017) is accepted, we know very high-cost growth (Category III) is associated with the program characteristics listed previously, and that those are largely absent in programs with lower cost growth (Categories I and IIa).

The significance that can be attached to Lorell et al. (2017) is, however, constrained by its inclusion only of Air Force programs that passed MS B during the years 1991–2001 and its small sample size. More concretely, several of the high-cost growth programs included were acquired with contracts that limited government oversight and, instead, placed more responsibility on the contractor for system performance. This approach was called Total System Performance Responsibility (TSPR), which, in retrospect, was associated with high-cost growth. As the authors note, use of TSPR was strongly encouraged by senior DoD leadership. A new administration ended the TSPR experiment in 2002 (McNicol, 2018). Consequentially, to the extent that TSPR drove the high-cost growth cases, it is necessary to be wary of using Lorell et al. (2017) to interpret cost growth in earlier and later periods.

In addition, a feature that Lorell et al. (2017) shares with most other well-known studies of cost growth complicates its application to acquisition policy. In words that are just beginning to be used commonly, Lorell et al. (2017) implicitly attributed cost growth to Errors of Inception, which are unrealistic features of the program approved at MS B. There are, however, two other major categories of cost growth:

- Errors of Execution: management errors made during program execution by government or contractor program managers (PMs); and
- Program Changes: changes made to the program post-MS B that are not forced by internal program developments, such as schedule slips or cost growth.

The meager evidence available suggests that cost growth due to Errors of Execution is small—on average, only a few percentage points—but that cost growth due to Program Changes is, on average, a bit more than 30% of average cost growth (McNicol, 2018). Note that a Program Change is conceptually different from "unclear, unstable, or unrealistic requirements" (Lorell et al., 2017), but the two are difficult to separate if the capabilities to be acquired were loosely defined at MS B. This author's judgment is that

Errors of Execution and Program Changes probably are relatively unimportant for the high-cost growth cases considered by Lorell et al., but this does not imply that they can be ignored in other cases.

Finally, Lorell et al. (2017) does not provide an explanation of the full range of cost growth we see in Category II. There are 95 programs in Category II—the bulk of the sample used here—and even if all of Category IIa is dropped out, the cost growth of the remaining 51 programs ranges from 30% to 100%. These programs are the dandelions of cost growth—not the most noxious of weeds but the most common.

Conjectures Motivated by 2017 RAND Study

No published study has tried to explain the differences in the magnitudes of cost growth across Category II programs. In fact, the topic has barely been noticed.

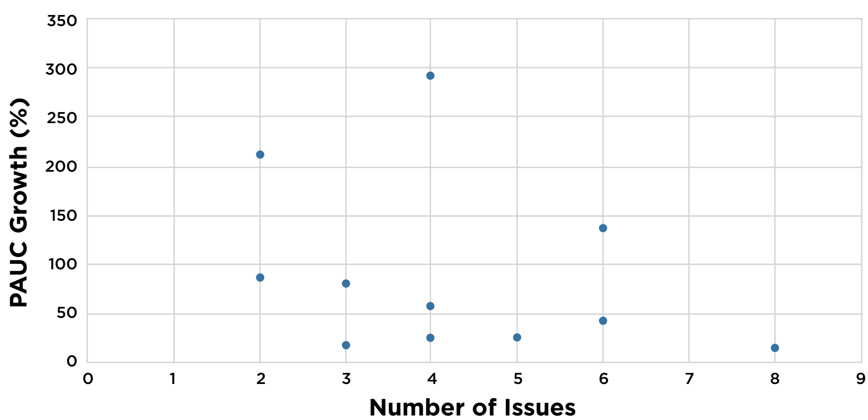
The most practical way forward on this problem is to hypothesize an explanation and then, to the extent possible, test it against data. The three possibilities considered here all concern Errors of Inception:

1. PAUC growth increases with the number of unrealistic elements in the MS B baseline; it is the number of poisons administered that counts.
2. The crucial cause of cost growth variation is the magnitude of the unrealistic elements in the MS B baseline—the sizes of the doses of poisons administered are crucial.
3. The extent of cost growth is determined by toxic combinations of MS B elements. That is, the poison is not any one substance alone, but is created by the interaction of several substances.

The first of these hypotheses can be tested easily, although crudely. Relevant data are presented in Figure 2. The data are drawn from Diehl et al. (2012), which provides a synthesis of the results of the 15 root cause analyses (RCAs) undertaken by RAND or IDA, as required by the Weapon Systems Acquisition Reform Act of 2009. (The RAND studies are reported in Blickstein et al. [2011, 2012]; Diehl et al. [2012] provide the references to the individual IDA studies.) Only 12 data points appear in Figure 2 because three of the 15 programs for which RCAs were done were major automated

information systems, not MDAPs. There is no visible association in Figure 2 between PAUC growth and the number of issues found in the RCAs and, in fact, the correlation between the observations on PAUC growth and the number of issues for these 12 MDAPs is statistically insignificant. The appropriate conclusion is that, at least for this sample, the magnitude of cost growth was determined by more than just the number of unrealistic elements in the baseline.

FIGURE 2. PAUC GROWTH AND NUMBER OF UNREALISTIC ELEMENTS IN THE MS B BASELINE



Note. Adapted from Diehl et al. (2012), Table 4, p. 12.

This brings us to the second hypothesis—that what matters for cost growth is the *extent* to which one or more features of the baseline approved at MS B are unrealistic. The obvious suspect is the cost estimate. If the cost estimate is, say, half of the realistic cost for the program, cost growth of at least 100% is almost certain to emerge. Cost estimates this unrealistic (and worse) are sometimes adopted. Another relevant example is the assumption in the MS B baseline on the annual buy rate during full-rate production; this also can be seriously unrealistic and have a substantial effect on PAUC growth. The SARs report MS B baseline unit costs. Unfortunately, the independent cost estimates, which would provide an indicator of the realism of the MS B baseline cost estimates, are not published. The situation is no better for other features of the program approved at MS B. In short, the data required to test the second hypothesis for a reasonably sized sample of MDAPs are not publicly available.

Finally, PAUC growth in the middle ranges—30% to 100%—may reflect the interaction of two or more features of the MS B baseline. The readiest example of this possibility is provided by immaturity of a critical technology and EMD schedule. The fact that a critical technology is somewhat immature at the start of EMD will not cause substantial cost growth if the technology is not required until relatively late in EMD. Schedule, of course, determines when "late" arrives. If the schedule is unrealistically short, it may force decisions on the immature technology that concatenate into a serious problem and cost growth. A similar example is provided by concurrence between the EMD portion of the program and the production portion. Concurrence is costly to the extent that it forces retrofits, and this, in turn, depends on how optimistic the EMD schedule is and, if EMD slips, just what parts are delayed.

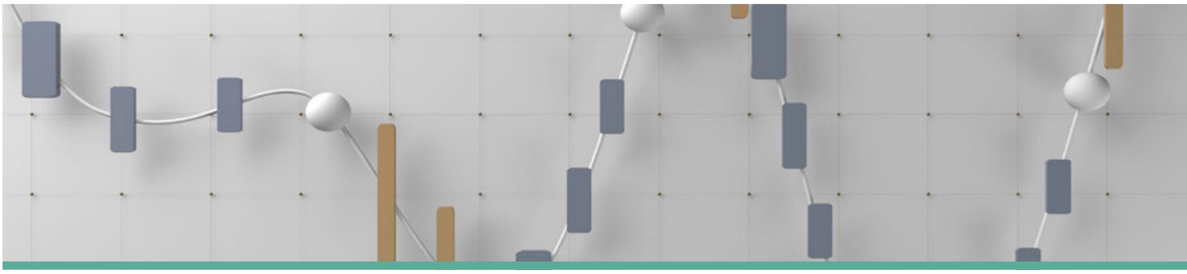
> **If the cost estimate is, say, half of the realistic cost for the program, cost growth of at least 100% is almost certain to emerge. Cost estimates this unrealistic (and worse) are sometimes adopted.**

A painstakingly careful study of an individual MDAP, ideally with cost growth in Category IIc, should be able to identify the causes of PAUC growth, estimate the magnitude of each, and characterize how interactions between various factors influenced PAUC growth. This would be a difficult, data-intensive, time-consuming task, but it could, and perhaps should, be done. The truly daunting prospect is that of accumulating a sufficient number of such studies to provide a sound basis for policy recommendations.

Root Causes of Cost Growth

This section takes up the question of whether recent work on the root causes of cost growth in MDAPs explains the clustering of cost growth observed in Figure 1, especially Category IIc. The term "root cause analysis" is defined further on.

The Senate Committee on Homeland Security and Governmental Affairs staff report on acquisition reform provides a convenient place to begin the discussion (Senate Report No. 113-28, 2014). This report provided—and probably still does—a fair representation of the opinions on the causes of cost growth from people who have been associated with DoD or the Congress. None of the experts proposed a theory of cost growth. However,



two—Thomas Christie and Paul Francis—in the course of their remarks, point to the basic elements of a theory of the root causes of cost growth based on incentives. These elements are as follows:

1. The context is long-standing criticisms of the results of the DoD acquisition process for MDAPs—cost growth, schedule slips, performance shortfalls.
2. Christie asserts that these problematic results are largely due to unrealistic assumptions embedded in the baselines approved at MS B. Francis takes a less definitive position on the extent to which cost growth is due to unrealistic elements in MS B baselines.
3. Christie and Francis both observe that competition for funding provides the PM of an MDAP with an incentive to propose unrealistic program assumptions for inclusion in the MS B baseline. Christie seems to suggest that this incentive applies to all MDAPs in all periods; again, Francis takes a less definite position.
4. Christie and Francis both assert that sometimes the Milestone Decision Authority (MDA) accepts a proposed MS B baseline in the face of creditable evidence developed during the MS B review that it contains some program assumptions that are significantly unrealistic.

Note that items 3 and 4 are sufficient conditions for the occurrence of cost growth: The unrealistic baseline is proposed, presumably by the PM, and then accepted by the MDA. In this context, “program manager” should be understood to refer to the PM, the Program Executive Officer (PEO), and any other, more senior officials who participate directly in the decisions.

It is important not to conflate a failure to fully fund the cost estimate in the MS B baseline and the realism of that estimate. The issue here is the realism of the MS B cost estimate; it is taken for granted that the cost estimate in the MS B baseline will be fully funded.

A root cause model is, as the label suggests, a model of the causes of cost growth, but it goes at least one stage upstream from the immediate, or proximate, causes of cost growth. For example, one common proximate cause of cost growth is an unrealistic EMD schedule. A root cause analysis attempts to say something useful about why the unrealistic EMD schedule was adopted. The obvious approach is to start with the decision to adopt an unrealistic EMD schedule and work back up the decision stream to identify the succession of decisions that yielded the unrealistic EMD schedule. This is an extremely ambitious, data-intensive, and in many respects analytically difficult approach. In contrast, McNicol (2020) takes an approach that is far easier and uses much less data. It seeks only to characterize the circumstances in which a decision to adopt a MS B baseline with substantial unrealistic elements is likely to occur.

The model is built on the premise that an unrealistic MS B baseline is more likely to be proposed by the PM and adopted by the MDA when competition for funds is more rather than less intense. The question then becomes: What governs the intensity of competition for funds and the ability of the PM to respond by proposing a MS B baseline with unrealistic elements? McNicol (2020) proposes: (a) funding climate—this is determined by several factors, the most volatile of which is the relative availability of funding for MDAP new starts; (b) a measure of the priority of the program—high priority programs are closer to the front of the line for funding; and (c) measures of changes over time in acquisition policy—the more stringent acquisition policy is, the less scope a PM has to propose an unrealistic MS B baseline. (A "high priority" program was defined as one that acquired a platform intended to play a major role in one of the Service's major warfighting missions, e.g., the F-22.) These variables are in the portion of the model concerned with cost growth due to unrealistic elements in the MS B baseline.

McNicol (2020) would excel at a more challenging version of the test that included (a) the difference in cost growth between MDAPs that passed MS B in bust periods and those that passed in boom periods; and (b) the difference in cost growth between high- and low-priority programs. These differences are substantial. For example, for the first bust-boom phase (FY 1965–FY 1986), the difference is 28 percentage points: 46% for the bust phase and 18% for the boom phase (McNicol, 2018). The model in McNicol (2020) provides a cogent explanation of these differences, which finds substantial statistical support. The conventional wisdom and the model implicit in Lorell et al. (2017) have no explanation to offer for either the large difference between bust and boom periods and the smaller, but still substantial, difference between high- and low-priority programs.

The general answer to the question posed in this article is this: The acquisition community has major parts, but not all, of an explanation of the proximate causes of cost growth in MDAPs due to Errors of Inception.

McNicol (2020) does not do any better than the other models in explaining the data in Figure 1, however. At first glance it appears that it might. In particular, high-priority MDAPs might be expected to be in Categories I and IIa and low-priority programs in Category IIc and III. Plausible though this conjecture may be, it is not consistent with the data. Thirty-one MDAPs are in Category IIc. Of these, 23 (about 74%) were low-priority programs. (Recall that all the programs in Figure 1 passed MS B in a bust period.) Low-priority programs, however, account for about 77% of the sample behind Figure 1. Using a standard chi-square test, these two proportions are not significantly different.

Conclusions

The general answer to the question posed in this article is this: The acquisition community has major parts, but not all, of an explanation of the proximate causes of cost growth in MDAPs due to Errors of Inception. A great deal of effort has gone into Category III over the years. We probably understand the causes of extremely high-cost growth reasonably well. As well as making a major contribution to our understanding of Category III programs, Lorell et al. (2017) give us a start on MDAPs with negative cost growth, and it probably would be easy to find additional factors involved. Overall, the literature has progressed to the point that deficiencies in understanding of Categories I, IIa, and III largely could be remedied by careful and judicious reading and synthesis. At present, however, no explanation satisfactorily accounts for the causes of cost growth in Categories IIb and, especially, IIc. Together, these two categories include over 40% (51 of 123) of the MDAPs in the sample used in this study.

The OIPT's established roles are to organize milestone reviews, ensure that the required documentation is available and meets quality standards, identify the issues raised in staff reviews, and resolve issues that can be resolved below the MDA level.

This absence is important because an explanation of the proximate causes of cost growth due to Errors of Inception provides a foundation for recommendations for changes in acquisition regulations and policies. Stripped to its essentials, the presumption is that if a cause of cost growth can be seen, solutions can be found in additions to, or modifications of, acquisition policies and regulations. But most important for Categories IIb and IIc, significant uncertainty prevails throughout the defense acquisition community about just what is causing the relatively large cost growth observed and, consequently, the appropriate policy response.

The leading possibilities are (a) the magnitude by which one or more elements in the MS B baseline (for example, the cost estimate) is unrealistic; and (b) the interactions of two or more elements. These have different policy implications. If the problem is that large errors in particular elements occur with some frequency, attention is directed to the staff organizations at the OSD level responsible for review of those elements. Alternatively, if the problem is a toxic interaction of two or more elements of the baseline, the spotlight falls on the Overarching Integrated Product Team (OIPT), or—beginning in 2018 for most MDAPs—whatever body plays the role of the OIPT at the Service level. The OIPT's established roles are to organize milestone reviews, ensure that the required documentation is available and meets quality standards, identify the issues raised in staff reviews, and resolve issues that can be resolved below the MDA level. On the assumption that a major proximate cause of cost growth is a toxic combination of elements in the baseline, it also presumably would fall to the OIPT to identify these elements and propose alterations of them in a way that avoids the problem of large cost growth.

A deeper insight into this topic is found in a comparison of comments made by Tom Christie and Paul Francis in the Senate Staff Compendium (Senate Report No. 113-28, 2014). Both assert that in a significant proportion of cases, the MDA accepts a MS B baseline in the face of creditable evidence that some of its elements are unrealistic, which is to say that in these instances, the MDA did not fully enforce DoD's acquisition rules. Christie's evident remedy is for MDAs to apply established acquisition policy. Francis, in contrast, takes the view that the acquisition rules and policies actually followed by MDAs have evolved over time under the pressure of events. From this perspective, the fault is not in the failure of successive MDAs to apply the rules as written, but in a lack of flexibility and realism in the written rules themselves. Having made this intriguing and provocative point, Francis unfortunately does not go on to identify what rules he has in mind and how, over time, they evolved into something more permissive than written acquisition regulations.

Implications for Further Study

This article can be read as suggesting further research on the extent to which the magnitude of cost growth of MDAPs reflects:

- The degree of unrealism in elements of the MS B baseline (e.g., how unrealistic is the cost estimate?); and
- The interaction of two or more elements of the MS B baseline.

These suggestions are not offered with enthusiasm because at best it would be extremely difficult to capture the data required for a creditable study. Anyone interested in the results of such studies should not be in a hurry.

In the face of this obstacle, someone interested in ongoing events in the acquisition process might decide to accept the limitations of the empirical literature, take what is useful, and go directly to a policy problem. The two empirical issues listed previously direct attention to the effectiveness of the MS B review process. In 1964, Robert McNamara established the first OSD-level process for oversight of MDAPs. This provided the trellis on which the MS B process and its institutions grew for the next half century and more. It perhaps is time to identify and then evaluate fundamentally different approaches. A topic that would be approached similarly, but which is different in substance, could take off from the premise that in some cases the MDA accepts a proposed MS B baseline in the face of creditable evidence that some elements are significantly unrealistic. It would be reasonable to assume further that such decisions are much more likely to occur in bust periods. During bust periods, senior officials were constrained to select from a menu that offered only unpalatable choices: delay new starts; stretch ongoing programs; truncate or cancel ongoing programs; launch new programs that will provide less capability than the threat warrants; or adopt unrealistically optimistic assumptions at MS B—especially on cost—for major acquisition programs. One question never asked, but which should be, is this: Given the circumstances assumed, was it at least sensible if not cost-effective to adopt a baseline with unrealistic features? And then, depending on the answer to this question, it is reasonable to ask whether the formal acquisition regulations should be modified to recognize the discretionary authority that senior officials may choose to exercise.

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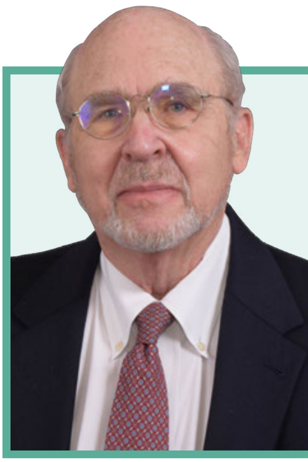
Author Biography



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CHALLENGES OF ADOPTING DEVOPS FOR THE COMBAT SYSTEMS DEVELOPMENT ENVIRONMENT

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The Department of Defense (DoD) is often exhorted to adopt best practices from industry, and more recently, innovation in software development as exemplified by Silicon Valley. Yet, the DoD is vastly different from industry in multiple aspects, and adoption of such practices is not as straightforward as in industry. This article investigates the challenges of adopting Development and Operations (DevOps) in the U.S. Navy for combat systems. The authors conducted interviews of multiple subject matter experts in the Navy and DoD familiar with software development, DevOps, and the DoD's acquisition processes. The observations collected from the interviews were organized and classified into either organizational, process, regulatory challenges, and technical challenges. The majority of the challenges cited were nontechnical challenges dealing with regulations, organization culture, and process. Knowledge of the challenges could help acquisition leaders in planning for, and adapting DevOps to, the Navy's acquisition process to improve DoD's software development and maintenance processes.

DOI: https://doi.org/10.22594/dau.21-870.29.01
Keywords: *Software Acquisition, Agile Methods, DevSecOps, Change Management, DevOps*

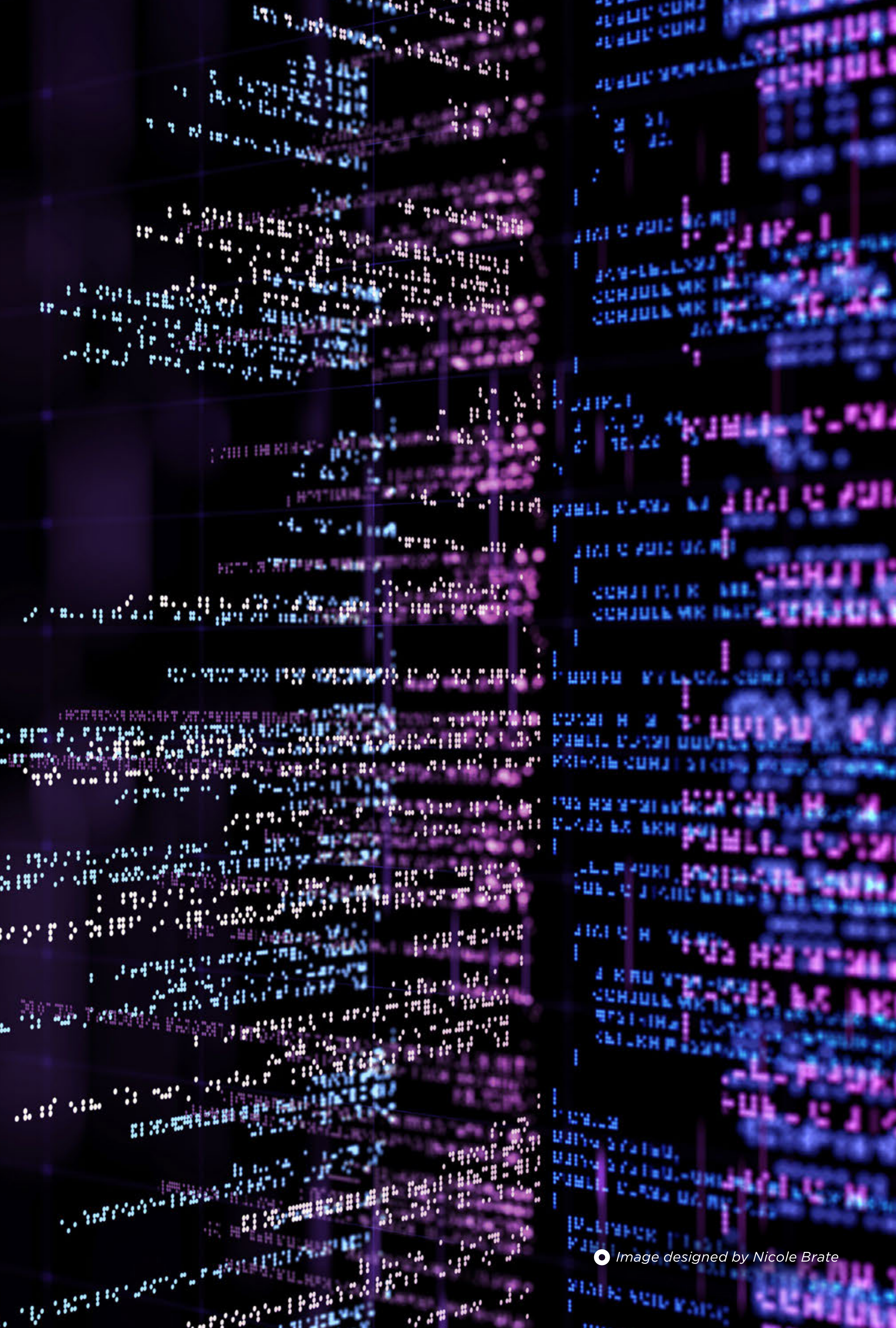
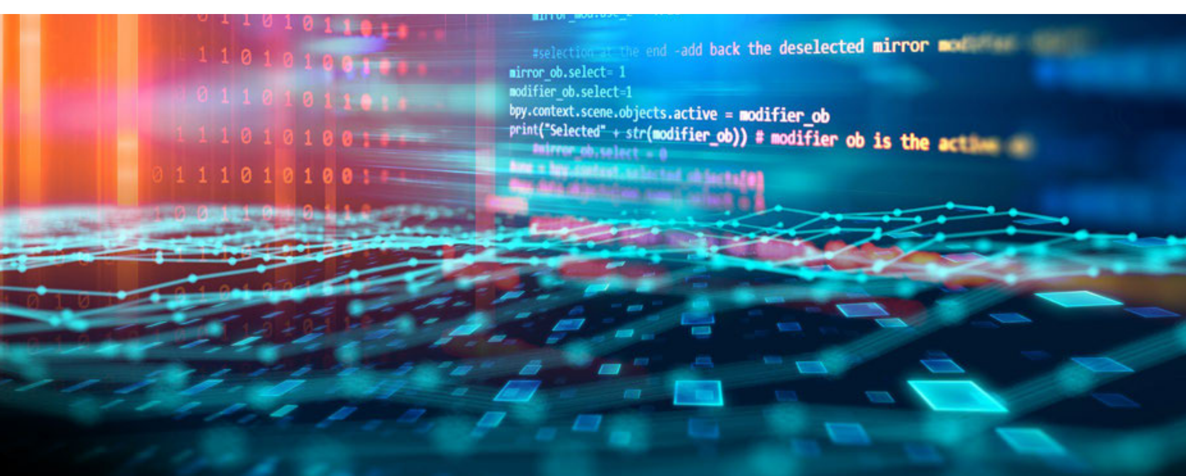


Image designed by Nicole Brate

The U.S. Department of Defense (DoD) acquisition process, system development process, and organizational mindset all evolved based on the design, development, and delivery of hardware systems. Yet, the software content of systems is increasing dramatically. Software differs signifcantly from hardware in important characteristics. Unlike hardware, software systems are intangible and are not subject to the laws of physics (Sommerville, 2021). This makes software easily deployable and updated with only a network connection. Consequently, software companies routinely push software updates to their customers, resulting in a continuous process of software development and deployment. One of the largest distinctions between hardware and software is the fact that software must be constantly updated by developers throughout its service life. In fact, the DoD finds that software maintenance, consisting of modifying and updating software to stay abreast of evolving operational needs, accounts for the majority of software budgets, and sailors commonly complain about slowness in updating software (McQuade et al., 2019). Industry has long recognized how software differs from hardware, and it uses different processes for software development than hardware development. Improving information flows between software development and operations, therefore, is a sound goal for the entire defense industry.



That the DoD struggles with delivering software to the forces in a timely manner is well documented (Brady, 2020; Pomerlau, 2016). This has prompted the DoD to look for new ways of speeding up the development and delivery of software-intensive combat systems. As part of these efforts, the DoD has sought to adopt best practices from private industry and Silicon Valley, in particular (Freedberg, 2020). These practices include agile software development and DevOps, which is the integration of software development (the "Dev") and operations (the "Ops") (Kramer & Wagner, 2019). The DevOps concept seeks to bring developers and operators into a harmonious relationship to improve communication, increase development speed, and reduce the rate of errors and inefficiencies in the implementation of new technology.

> **DevOps is not just a new way of doing things, but DevOps is a new way of thinking about how the Navy develops and delivers combat systems.**

Adopting new ways of work such as DevOps is never an easy task for large organizations such as the Navy. This article investigates the following question: *What are the challenges of adopting DevOps in the U.S. Navy for combat systems?* To identify the obstacles, we start with a literature review of DevOps implementation in industry. We use the literature review to develop interview instruments and conduct 11 semistructured interviews with subject matter experts in defense software acquisition. The article categorizes the interviewees' observations according to the types of challenges cited by the interviewees. For each challenge, we elaborate on the issue facing the Navy and how industry has approached the issue.

Background on DevOps and Agile Methods

DevOps, as illustrated in Figure 1, creates a work environment where development, testing, and operations are part of a single infinite cycle (Kim et al., 2016). The DevOps concept is a large departure from traditional DoD systems engineering models such as the Vee model that assumes top-down and sequential development with a specific delivery date and transition into operations. In DevOps, the developers provide a product to the testers who certify that it is safe, reliable, and capable of meeting an operational need. The testers pass testing results back to the developers in near real-time so the data can be used to make improvements and to fix shortfalls within the software or hardware. With these improvements made, the new change or fix is deployed to the fleet. In the case of the Navy, the operators and users are sailors stationed on ships or submarines who both operate and maintain combat systems. After using the combat systems, sailors and their commanders then provide feedback to the developers and testers so that they can improve the combat system and the testing methods used to certify it for operation. Unlike current system development processes in the Navy, this cycle happens for the duration of the life of the program.

FIGURE 1. TYPICAL DEVOPS CYCLE

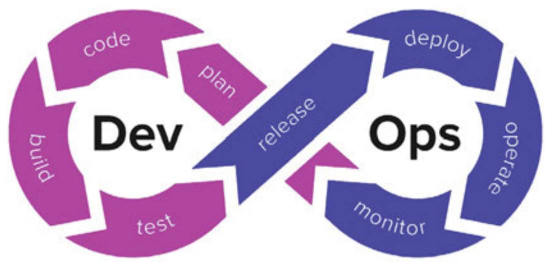


TABLE 1. LIST OF DEVOPS CONCEPTS

DevOps Concept
Open Communication and Close Collaboration
Continuous Experimentation
Continuous Feedback
Continuous Integration
Operational Flow

While we describe DevOps as a process, it is enabled by a set of philosophies and practices intended to increase the speed of development and delivery of capabilities while still ensuring the efficacy and safety of those capabilities. DevOps is not just a new way of doing things, but DevOps is a new way of thinking about how the Navy develops and delivers combat systems. DevOps requires a tighter integration of the development, testing, and operations of these combat systems into a symbiotic web of constant improvement. DevOps delivers value when organizations adopt the key concepts listed in Table 1.

Literature Review

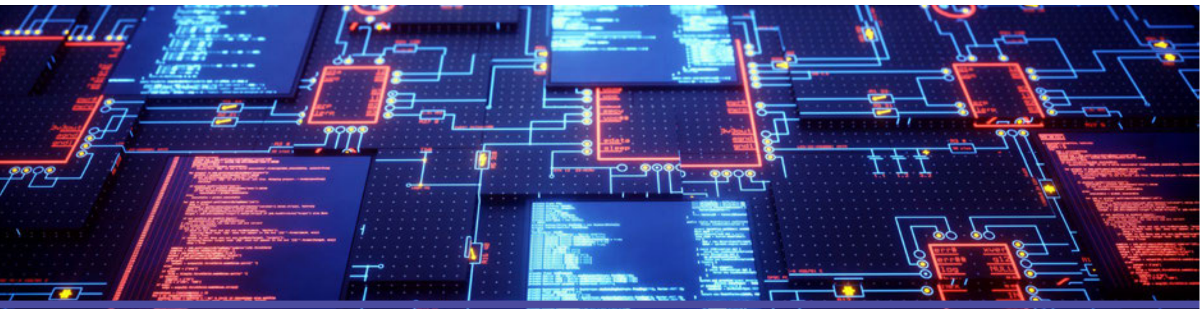
The adoption of DevOps by organizations has been widely studied in the software industry, especially for organizations delivering software as a service or purely software products. The majority of the work is based on case studies. Table 2 summarizes a few of the studies on challenges of DevOps' adoption. In the government sector, there are far fewer papers. Cagle et al. (2018) describe how federal organizations continue to struggle with adoption of agile processes, and they recommend changes to requests for proposals that can help because contractors perform much of the software development. Morales et al. (2018) recommend questions to consider when implementing DevOps in highly regulated environments like the DoD and suggest only a partial DevOps might be possible. Robertson and Bonner (2020) state how agile software practices were developed to capitalize on particular customer characteristics in the commercial sector, and for the DoD to be successful with DevOps, it must tailor the agile concepts and practices to its unique situation.

TABLE 2. CHALLENGES OF DEVOPS ADOPTION CITED IN LITERATURE

Source	Challenges Cited	Citation
Senapathi et al. (2018)	Resistance to cultural change and work process change Staff skills recruitment Tools adoption	6 interviews in a single company
Luz et al. (2019)	Automation Transparency and data sharing Continuous measurement Quality assurance	15 interviews in a single company
Lwakatare et al. (2016)	Culture of continuous improvement Test management Deployment process automation Feedback of operational data	Case study and interviews of 4 European companies developing embedded systems
Riungu-Kalliosaari et al. (2016)	Communication between operations and development Culture changes to implement DevOps Industry constraints on data sharing	Case study and interviews of 3 European companies
Leite et al. (2019)	Process redesign for continuous delivery Tool integration	Literature review of DevOps papers

The use of DevOps for combat systems involves the tight integration of hardware and software, which is called embedded systems in the literature. Chaillan and Yasar (2019) note DevOps remains a problem for embedded and real-time systems in the DoD, which includes combat systems. A 2016 paper claimed there was no evidence of DevOps in the embedded domain (Lwakatare et al., 2016).

The review of the literature shows most studies have examined consumer software and software as a product. Far fewer papers address DevOps challenges in the DoD—a highly regulated environment—nor is there much experience on DevOps for embedded software as found in combat systems. This article contributes to the literature a study of the obstacles to adoption of DevOps in the U.S. DoD.



Research Method

Our research question was *What are the challenges in implementing DevOps in the Navy?* To address the question, we used a qualitative research method of semistructured interviews. Qualitative research provides a rich and effective means to identify the factors or issues affecting one or more outcomes (Kvale, 1994). In our case, we use the qualitative research approach to identify those factors obstructing adoption of DevOps. The research goal is to classify and describe the challenges unique to Navy acquisition in adopting DevOps.

To research the topic of DevOps adoption, we started with a literature review of DevOps and its implementation in industry (see Miller [2020] for full literature review). We relied heavily on the change management literature and viewed the research question through the lens of change management theories. We categorized challenges to DevOps adoption, and used this information to develop and organize our interview questions. The semistructured interviews lasted anywhere from 45 minutes to 2 hours and consisted of five to six starting questions concerning the technical, cultural, regulatory, and process challenges the Navy must confront in its attempt to adopt best practices for software development. The interviewers asked the respondents to draw upon their professional experiences, current work in the field, and knowledge of both the Navy's acquisition programs as well as those in private industry. Table 3 lists the subject matter experts who were interviewed, along with their positions and brief descriptions of their expertise.

TABLE 3. INTERVIEWEES

Interviewee	DevOps Experience
Department of Navy (DoN) contractor for Naval Air Systems Command	Over 30 years as a Naval Officer and 13+ years working as a contractor and Agile consultant.
Senior Software Engineer for Naval Information Warfare	Over 25 years working with Navy IT systems and championing DevOps and Agile practices.
Chief Engineer at DoD contractor	Over 20 years as a Naval Officer and 15+ years as a software developer implementing Agile and DevOps practices.
Project Manager at Program Executive Officer (PEO) Integrated Weapons Systems	Over 15 years as an officer in the Naval Reserve and is employed doing IT development using DevOps and Agile practices in civilian life.
DoN contractor at PEO Integrated Weapons Systems	Over 40 years as a Naval Officer and civilian Acquisition Professional with a focus on combat systems certification and testing.
Program Manager at Naval Air Systems Command	Over 20 years as a Naval Officer and Acquisition Professional with a background in rapid prototyping and Agile development.
Senior Software Engineer at PEO Integrated Weapons Systems	Over 15 years developing and testing Naval weapons and cyber systems.
Assistant Program Manager at PEO Integrated Weapons Systems	Over 10 years as a Naval Officer and Acquisition Professional.
Assistant Program Manager at PEO Soldier	Over 15 years of enlisted and commissioned experience in the Army and a background in Agile development.
Scrum Master at Air Force's Kessel Run Program Office	Over 10 years' enlisted, commissioned in the USAF, and formal education in IT systems.
Systems Certification Manager at PEO Integrated Weapons Systems	Over 10 years as a DoN civilian.

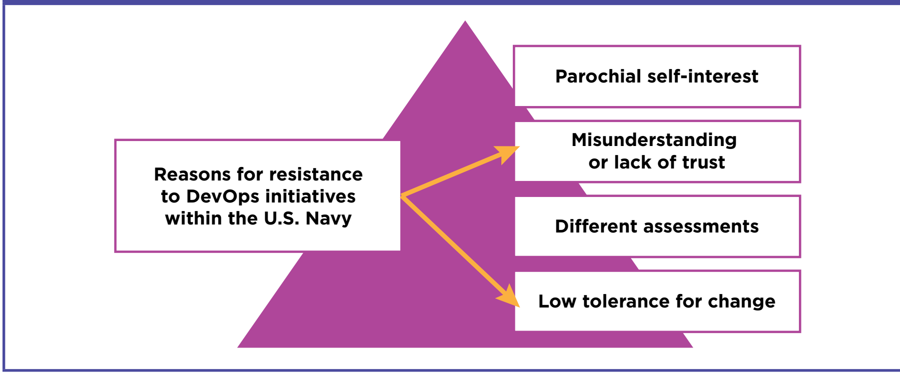
Interview Analysis

This section describes the analysis of the interview observations. We classified the interview observations according to the type of challenge, and we link it to the relevant literature. When appropriate, we quote and paraphrase the interviewees.

Cultural Challenges

Resistance to the introduction of new ways of working is common, and DevOps involves significant changes to work flow, job description, and other aspects of the work environment. Gibson et al. (2012) identified four key reasons for resistance to change: (a) the self-interest of the resister, (b) the resister's misunderstanding of the change, (c) the resister having a different assessment of the best course of action for change, and (d) a low tolerance within the organization for change. Within the Navy, respondents identified the second and fourth reasons as the most pressing (see Figure 2).

FIGURE 2. PRIMARY REASONS FOR RESISTING CHANGE TO DEVOPS WITHIN U.S. NAVY



Note. Adapted from Gibson et al. (2012).

The Navy has a history of resistance to change due to simple institutional inertia (Hall & O'Connor, 2018) as well as a desire to preserve tradition (Buhl, 1974). As was noted by one of the respondents who served in the Navy, a sailor's favorite phrase when asked why a task is completed a certain way is "That's the way we've always done it" (Anonymous acquisition professional personal communication, February 10, 2020). This deep-rooted resistance to change can make implementing DevOps a difficult task. The Air Force found the hardest hurdle to overcome when implementing DevOps practices within the F-22 Raptor program was to change the program's culture (Ulsh & McCarty, 2019).

One cybersecurity engineer stated that the misunderstandings about the nature of DevOps and resistance to change within the organization have hindered prior attempts to adopt DevOps and agile business practices. Once again, this is reflected across the entire DoD. In an annual survey of major acquisition programs in 2019, the U.S. Government Accountability Office found that of the 22 programs that claimed to be agile, only six conformed to the best practices of private industry (Freedberg, 2020).

Risk Aversion

Chief among the cultural hurdles is the Navy's aversion to risk in acquisition programs. One respondent stated that the Navy's budget has decreased since the Cold War, yet combat systems costs continue to increase, which creates an environment where acquisition programs are increasingly wary of any and all risks. This has resulted in a climate where, as one program manager at Naval Air Systems Command (NAVAIR) lamented, there is, “no tolerance for risk within the Navy acquisitions and development hierarchy” (Anonymous acquisition professional, personal communication, February 10, 2020). This makes any deviation from established norms difficult to implement, and this sentiment is contrary to the DevOps culture of an environment where personnel feel it is safe to take risks and potentially fail (Forsgren et al., 2018). DevOps adheres to the fail-fast mentality because it encourages developers to test ideas, emphasizes the value of the knowledge gained by any failures, and allows developers to be more creative in responding to emergent system requirements.

Aversion to risk manifests itself in the regulatory environment in which the Navy operates. Of the 11 respondents, eight said the Navy’s attempts to innovate are stifled by the rigid statutes and regulations required by Congress to ensure the government shoulders as little risk as possible in acquiring new combat systems. These statutes and regulations are written into DoD and Navy policies that dictate how to write contracts, how to decide upon contract awards, and how the government’s money can be spent. As one consultant at Naval Sea Systems Command (NAVSEA) opined, “The reason we have the rules we have is because we messed up in the past, and needed to codify rules to prevent those screw-ups in the future” (Anonymous acquisition professional, personal communication, February 10, 2020).

One respondent stated that the Navy’s budget has decreased since the Cold War, yet combat systems costs continue to increase, which creates an environment where acquisition programs are increasingly wary of any and all risks.

During the interview process, every respondent expressed disfavor with the way contracts were written and awarded. One acquisition professional at NAVSEA stated, “We make contract awards based upon price alone” (Anonymous program manager, personal communication, February 10, 2020). The manager for a program in the Air Force mentioned, “Military contracts make things too specific” and because of that “We can’t provide the best solution” to the warfighter (Anonymous program lead, personal communication, February 14, 2020).

The Navy's need to specify all requirements in contracts is problematic for DevOps (Jacobs & Kaim, 2021c). In DevOps, the developers work closely with operators to determine their needs and identify the work for the next sprint during the Scrum process (Forsgren et al., 2018; Gilman et al., 2019). During these sprints, developers and operator advocates meet daily to ensure that the work being performed aligns with the needs of the customer regarding functionality and user experience. This close working relationship builds trust between the customer and the developer, and nullifies the need for rigid contract language to ensure that the developer will deliver an acceptable product. To adopt DevOps, the Navy will need to overcome these trust barriers and build closer working relationships with its contractors.

Vendor Lock-in

Risk aversion affects not only the Navy, but also the contractors who design and build the Navy's systems. Because development expenses are so high and profit margins so thin, contractors meticulously protect their intellectual property (Gilman et al., 2019). As one contractor mentioned, the result is the Navy relies on proprietary systems and the original contractor is the only one qualified to perform follow-on integration work and capability updates (Anonymous agile consultant, personal communication, February 18, 2020). Because of the vendor lock-in effect, it is very important to contractors to win the initial award and, as a result, they tend to take a conservative approach and contest contract awards when they lose.

> **If the Navy continues to rely on proprietary software and not open standards, then it will continue to be unable to keep up with the pace of change in both the private sector and its adversaries.**

Contrast this with private industry that uses open source tools and software (Anonymous senior scientist, personal communication, February 18, 2020). By relying on open source solutions, private industry is able to leverage a larger pool of vendors and contractors, and therefore more possible ideas for solutions. As one consultant working on unmanned aerial systems remarked, "We need to be better about designing open systems" so that "we're not tied to proprietary software or hardware" (Anonymous agile consultant, personal communication, February 18, 2020). Failure to adopt open source solutions will cause continual problems within systems development

programs. For instance, USS *Zumwalt* (DDG 1000) was initially designed to use computer servers from Microsoft, but during the middle of development for Zumwalt, Microsoft sold off its server hardware division. Because the requirements for the ship were written specifically for Microsoft hardware, this change led to unnecessary delays due to the slow requirements generation and approval process. If the Navy continues to rely on proprietary software and not open standards, then it will continue to be unable to keep up with the pace of change in both the private sector and its adversaries.

High Reliability Organization

One interviewee said, "The Navy has to live in a world where we kill people and break things"; consequently, there is little room for bugs or defects in the systems that are given to the fleet (Anonymous cyber engineer, personal communication, February 6, 2020). The Navy has the organizational mindset of a high-reliability organization (HRO). An HRO operates specialized systems, which are deeply interconnected, are potentially hazardous, and have a high risk of catastrophic failure (Shrivastava et al., 2009). The combat systems the Navy develops are complex and tightly coupled, meaning that errors are difficult to diagnose and any defects can potentially propagate quickly throughout the system of systems (Roberts, 1990; Van Stralen, 2017). Example HROs are found in nuclear power plants and airlines.

Many software organizations such as Microsoft or Google do not need the same level of quality assurance as HROs. If Google or Microsoft push a software update that breaks their users' systems, they simply have to launch a media campaign to apologize. If the Navy accepts a defective combat system, then sailors and civilians can possibly die. In the context of Navy DevOps, the culture of high reliability results in approvals for release being slower to achieve, testing being more thorough, and requirements for quality control being more stringent. This will inevitably mean that the Navy cannot achieve the same level of development speed as the technology industry leaders it seeks to emulate since it has higher standards to meet. But, as one acquisition professional at NAVAIR expressed, "DevOps may not make us too much faster, but it's going to make us on time" (Anonymous agile consultant, personal communication, February 18, 2020).

As one program manager mentioned, the change leader must "defeat the antibodies to change within the Navy's bureaucracy" (Anonymous program manager, personal communication, February 14, 2020). Another software engineer mentioned, "The novelty of the idea of DevOps and the confusion surrounding just what exactly it is, has resulted in many in the Navy's upper echelons of leadership not understanding what must be done to bring about change or how to communicate its necessity" (Anonymous cyber engineer, personal communication, February 6, 2020). An agile consultant stated that this is further compounded by the short duration in which leaders remain in command (typically 2 to 3 years) and their high turnover rate (Anonymous agile consultant, personal communication, February 10, 2020). This makes it difficult to carry out long-term change leadership, especially for something like the adoption of DevOps that will likely take a decade or more to be fully realized. A consultant at NAVAIR lamented, "The Navy needs someone at the [Senior Executive Service] or Flag level to lead the charge." That same consultant also stated, "The Navy needs a character like Hyman Rickover with passion, drive, and horsepower to get the organization charged and aligned to the future of DevOps" (Anonymous agile consultant, personal communication, February 10, 2020).

Regulatory and Process Challenges

All the respondents were quick to point out that the Navy and the DoD labor under many regulations and statutory requirements dictating how they will operate, acquire new combat systems, and perform development of new technologies. Navy acquisition exists in what is known as a highly regulated environment (HRE). An HRE is an environment in which heightened security, access controls, segregation of duties, inability of personnel to discuss certain topics outside of specific areas, and the inability to take certain artifacts off premises are put in place (Morales et al., 2018). An HRE is used when the intellectual property and methods being developed must be safeguarded from theft and all parties involved are sworn to secrecy. This directly conflicts with the DevOps tenet of sharing information openly and freely between all parties involved with the development of a system (Kim et al., 2016).

> **The combat systems the Navy develops are complex and tightly coupled, meaning that errors are difficult to diagnose and any defects can potentially propagate quickly throughout the system of systems.**

The Navy has, as one contractor for an ACAT I program mentioned, "a certain level of stricture and structure that makes it harder to implement DevOps than the civilian sector" (Anonymous chief engineer, personal communication, February 18, 2020). The Navy must limit the open sharing of capabilities, limitations, and technical details about its combat systems because release of such information is a security threat. This forces the Navy to work around "security concerns, classified information, non-ideal hardware restrictions," as well as compartmentalization of vendors (Gilman et al., 2019). But the requirements for secrecy are not the only regulations that the Navy must abide by when developing combat systems. The Federal Government also imposes strict requirements on the funding (Critical Cost Growth, 2012), acquisition strategy (Acquisition Strategy, 2015), and testing and evaluation of new systems (Deputy Assistant Secretary of Defense, 2011; Operational Test & Evaluation, 2010). This means that any new system must meet certain milestones and performance criteria before being accepted, and that failure to do so may end in the program being canceled (Gilman et al., 2019). This contradicts the best practices of DevOps that dictate that the capabilities of a system should be built gradually. To place this in colloquial terms, DevOps requires that an elephant be eaten a bite at a time with small, frequent updates (Senapathi et al., 2018), whereas the DoD acquisition process requires the elephant be eaten all at once.

Evolving Requirements

The Joint Capabilities Integration and Development System (JCIDS) process determines the requirements for a system and involves the generation of many documents including the Initial Capabilities Document (ICD), the Capabilities Determination Document (CDD), and other documents, which are reviewed and need approval during milestones A and B (Chairman of the Joint Chiefs of Staff, 2018). JCIDS is a top-down and plan-based approach, generating a stringent documentation of requirements in a legal manner suitable for a contract (Manning, 2020). The requirements process is the initiation of any acquisition program and forms the basis for all design and engineering decisions that will be made within that program.

All the respondents were quick to point out that the Navy and the DoD labor under many regulations and statutory requirements dictating how they will operate, acquire new combat systems, and perform development of new technologies.

The requirements documents should incorporate feedback and input from sailors and officers in the fleet. Unfortunately, that isn't the case as an acquisition consultant at the Navy's Program Executive Office Integrated Warfare Systems relayed, "Currently Sailors have little say in what goes into combat systems" (Anonymous senior scientist, personal communication, February 18, 2020). Furthermore, the requirements in the CDD are often written to describe specific functions, instead of outcomes for the fleet, reflecting "what the Navy needs" (Anonymous senior scientist, personal communication, February 18, 2020; Thompson, 2019). The plan-based approach is in opposition to how requirements are defined in a DevOps system that puts customer needs as the top priority (Kim et al., 2016). These needs are captured during daily or weekly scrum meetings in which the sprints (development periods) are planned. In each of these scrum meetings, a customer advocate champions the needs of the customer to ensure that the finished products are satisfactory (Barrett & Claxton, 2005). The guiding principle in private industry is to provide value to the customer and focus on outcomes for them (Anonymous testing manager, personal communication, February 10, 2020). This means that if the finished product is functional but doesn't provide exactly what the customer is looking for, or if the user experience is subpar, then it is considered a failure. The possibility of failure is avoided by meeting frequently with the customer advocate to review the progress being made and determine whether what is being developed still meets their needs or not. By implementing direct feedback from the customer, the developers are better able to provide successful products.

Certification and Testing Process

Testing is an integral part of the DevOps process. But unlike private industry, where all testing is rolled into one constant cycle, the Navy conducts testing in discrete stages that are tied directly to milestones in the combat system's life cycle. Furthermore, the Navy differentiates between developmental test and evaluation (DT&E) and operational test and evaluation (OT&E) (Barrett & Claxton, 2005). DT&E, performed during the technology development and engineering and manufacturing phases of development, is conducted to prove design concepts, demonstrate technological maturity, and identify integration problems prior to final prototyping. OT&E, carried out at the end of the engineering and manufacturing development phase, uses the actual system to determine whether the system is operationally effective and operationally suitable (Anonymous acquisition professional, personal communication, February 12, 2020).

Testing within the Navy is carried out under the authority of the program management staff with either the contractor (in the case of DT&E) or the Navy's operational testing command (in the case of OT&E) performing the testing. This testing must be conducted within the guidelines of the DoD's Director of Developmental Test and Evaluation and Director of Operational Test and Evaluation, respectively (Ullman, 2019). All testing is based on, and conducted in accordance with, each program's test and evaluation master plan (TEMP), which derives from the capabilities documents produced during the initial design phase of development via the DoD requirements generation process. This TEMP ties testing events to specific capability requirements as well as to development milestones and serves as the "contract between program management staff, systems integration experts, the contractors, and [Navy's operational testing command] for what is to be tested," as one contractor at NAVSEA explained (Kramer & Wagner, 2019).

This testing procedure was born out of a need for the Navy to develop complex hardware systems and to prove their efficacy prior to delivering them to the fleet. This need to develop hardware alongside the software forces the developers to design tests and divert resources for the test equipment necessary to perform those tests for the hardware (Ullman, 2019). This means that any development of combat systems using DevOps must include detailed test planning and plentiful developmental testing early in the project (Anonymous acquisition professional, personal communication, February 12, 2020). Hardware development also results in rigid testing schedules that do not respond well to changes or delays. As one expert in how the Navy performs testing revealed, the TEMP usually takes years to get approved, as it has to be reviewed by program management staff, systems integration experts, the Navy's Warfighting Requirements and Capabilities Office (which is responsible for system requirements and resource allocation), and the DoD directors for test and evaluation (Jacobs & Kaim, 2021a). This expert's example was the TEMP for USS *Gerald R. Ford* (CVN 78). The *Ford's* TEMP took 10 years to make it "through the labyrinth of bureaucratic red tape" for approval (Anonymous acquisition professional, personal communication, February 12, 2020) because every time a change was made in the technology being used during the ship's decades of development, the TEMP had to be updated and go back through the entire approval process from the start. This delayed testing and ultimately the final delivery of the ship to the Navy.

Contrast this with the way testing is performed in a DevOps environment where the prevailing theory is to break the software early and often so that weak points and inefficiencies in the code can be discovered and fixed quickly (Hofmann et al., 2018). Using these agile testing practices, a system can be updated and improved rapidly due to the massive amount of data available to the developers to identify problems and adjust code or hardware components. Once again, the goal for testing in a DevOps environment is to shorten the time it takes to build a system, test it, and put the results from those tests back in the hands of developers (Shahin et al., 2017). Like the Navy, strategic planning of testing is needed to ensure that the testing is adequate for pushing the system to its limits and testing its functionality. Oftentimes, this planning is performed using software that integrates directly with the testing suite to provide better collaboration throughout different departments in the company (Gilman et al., 2019). Also like the Navy, private industry leverages cross-team testing where the team responsible for testing is different than the team that developed the product. It is claimed that this cross-pollination of testing and development teams allows for the detection of defects faster. The Navy must adapt its current testing practices to provide for better cross-team collaboration and a higher volume of tests in a shorter amount of time.

Software Certification and Testing Process

Software systems have a second analogous process that they must undergo to be approved for use on Navy computer networks. This process is part of the DoD Information Assurance certification process and results in the software earning an authority-to-operate certification (Anonymous senior scientist, personal communication, February 18, 2020). The main focus of this certification process is to ensure the security and integrity of the DoD's IT systems. Similar to the systems certification process, software must be tested against security requirements; those test results must then be reviewed by an authorizing official, and upon successful completion, that official issues the certification allowing the software to be loaded onto Navy computers and servers.

The goal for testing in a DevOps environment is to shorten the time it takes to build a system, test it, and put the results from those tests back in the hands of developers.

Like the systems certification process, the Information Assurance certification process moves at a slow pace and requires manual approvals and initiation of testing at specific program milestones (Obicci, 2017). Every expert interviewed mentioned that the certification process moves too slowly and the requirements needed to achieve certification are too cumbersome. A computer scientist at Naval Information Warfare Systems Command (NAVWAR) mentioned that the ideal process would allow for a continuous certification as well as cross-compatibility between systems so that software is able to be loaded on any system once it is deemed "safe."

Now contrast the slow pace of the Information Assurance certification process with the continuous Risk Management Framework (RMF) process that is typically used in private businesses (Obicci, 2017). The RMF applies the same ideas of continuous learning and integration to information security to reduce the time it takes to detect security threats and respond to them (Anonymous cyber engineer, February 6, 2020). The RMF does this in a simple process of identifying potential risks, prioritizing those risks based upon their threat to the customer and developer, developing mitigation strategies, enacting those strategies, and then testing them (Ullman, 2019). These test data are then fed back into threat assessment. This means that the threat assessment is a continuous, ongoing process instead of a single event.

> **Similar to the systems certification process, software must be tested against security requirements; those test results must then be reviewed by an authorizing official, and upon successful completion, that official issues the certification allowing the software to be loaded onto Navy computers and servers.**

Technical Challenges

Though the nontechnical impediments took center stage during the interviews, there were still two technical challenges that the respondents were not sure how to address. These challenges were how to perform hardware development using DevOps or agile methods, and how to implement data feedback loops while still fulfilling the requirements for data security and classification. The three engineers who were questioned were confident that technologies and software used in private industry could be adapted for purposes of the Navy's acquisition programs. As one mentioned, "Private industry has been doing [DevOps and agile] for years" and the software is "out there" and readily available (Jacobs & Kaim, 2021b).

Hardware DevOps

The largest technical challenge preventing the Navy from implementing DevOps is that the Navy's combat systems comprise both hardware and software. Software development is iterative and incremental, with each update and patch serving as a building block towards the overall capability of the system (Schuh et al., 2016a; Ullman, 2019). Contrast the iterative and incremental approach with hardware programs that view the addition of capability requirements as requirements "creep." This creep often causes ambiguity in the primary capabilities of the system, difficulties in systems integration, subpar systems performance, cost overruns, and eventually project cancellation (Schuh et al., 2016b). The defense acquisition process is intentionally rigid because they want to establish requirements early in the design process and avoid costly design revisions and physical rework during manufacturing.

To date, very little literature has been written regarding the adaptation of DevOps or agile methodologies to hardware development. This is due to the nature of hardware development and the need to invest heavily in up-front material costs for hardware as well as in testing equipment (Anonymous acquisition professional, personal communication, February 10, 2020). The use of DevOps practices within hardware development is also confounded by the need to develop hardware on which to run software (Anonymous senior scientist, personal communication, February 18, 2020). Unlike pure software systems and development programs, many of the systems like radars and missiles are not hardware-agnostic and need specific hardware developed to meet operational needs. This means that the hardware must be developed before or in conjunction with the software. This forces the need to find ways in which to divorce the development and updating of software from hardware (Anonymous program manager, personal communication, February 10, 2020).

Separating the software from the hardware would make for simpler development programs and allow software development to be unhindered by hardware limitations. As one scientist at NAVWAR explained, "The hardware update tempo is much slower. Software can be updated daily but hardware takes years" (Anonymous senior scientist, personal communication, February 18, 2020). That being said, due to the Navy's culture as an HRO, this means that any integration of hardware and software must still be able to function safely and reliably. Furthermore, hardware becomes obsolete much faster than software. In the current "waterfall" Defense Acquisition System that takes a decade or more to come to fruition, this obsolescence of hardware creates a "tech refresh spiral" that leads to nearly "endless requirements creep and the eventual death of programs" (Anonymous acquisition professional, personal communication, February 10, 2020). These facts mandate that any adoption of DevOps methods in the hardware domain make sufficient use of configuration management tools to ensure functional integration of differing levels of hardware maturity. As the same scientist at NAVWAR clarified, "The goal isn't how to do agile hardware but how to manage obsolescence" (Anonymous project manager, personal communication, February 12, 2020).

Data Feedback

DevOps depends on the ability of the organization to collect and distribute continuous feedback on the combat systems to the developers. Gathering operational data on a system is not an entirely foreign concept to the Navy because data are required for the Defense Information Assurance certification and systems certification processes. However, data collection in the Navy is neither automated nor continuous. A testing manager at NAVSEA said, "The Navy currently relies upon instrumentation for tests that must be installed manually and combat systems must be configured to collect and store detailed data" (Anonymous senior scientist, personal communication, February 18, 2020). The data must then be manually packaged and couriered back to developers and engineers for analysis, as there is no automatic system to collect and transmit the data back ashore to developers (Anonymous assistant program manager, personal communication, February 17, 2020).

The Navy not only lacks the infrastructure to automatically collect and distribute the data, but it also lacks the personnel needed to make sense of all the data. A software engineer at NAVWAR explained data analysts in private industry are often used to analyze and interpret data to answer questions such as, "Are we effective?" or "Can we accomplish the mission better?" (Anonymous acquisition professional, personal communication, February 18, 2020). These data analysts play a crucial role in finding connections between the data and root causes of subpar performance. They can also play a role in better understanding customer needs. For instance, when a customer says that a user interface is "bad," the data analysts can perform analysis and find data to show that what the customer meant by "bad" was actually slow loading times.

> **The sharing of data between operational and developmental organizations as well as between government and contractors goes against the normal way the Navy does business.**

This kind of interpretation for the customer is no less important in the DoD. As one assistant program manager at PEO Soldier explained, the Army needs the data feedback and analysis to understand "how better physical training scores correlate with better marksmanship" (Meyer, 2014). Such feedback can help the Services better design the systems including the nonmateriel aspects of doctrine, training, and so forth encompassed by the acronym DOTmLPF-P (Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities-Policy). Unfortunately, the Navy and the DoD as a whole lack the number of data analysts needed to support all of their acquisition programs (Meyer, 2014). This is a critical need that must be filled for DevOps to work.

Increased Exposure to Security Risks

Within the DoD, the more common term is actually DevSecOps to emphasize the importance of ensuring security because the continuous updating and feedback leads to greater exposure to security risks. The sharing of data between operational and developmental organizations as well as between government and contractors goes against the normal way the Navy does business.

Conclusions

Throughout the 11 interviews and through all of the correspondence gathered from respondents, a trend became clear that despite the technical nature of DevOps, the respondents' largest concerns were with the cultural, organizational, process, and regulatory hurdles that stand in the way of the Navy adopting DevOps. The adoption of DevOps requires a drastic organizational and cultural shift within the Navy to establish the necessary work processes, individual training, responsibility, and policies. Table 4 shows the challenges identified through analysis of the interviews and classifies them according to the DevOps concepts identified in the literature review. During the interview process, it became apparent that these challenges are all interconnected and will require a holistic approach to change. The respondents all said the nontechnical problems must be addressed before any technical solution can be found. The two main technical challenges were (1) how to perform DevOps for hardware and (2) how to establish an infrastructure for collecting and using feedback data from the fleet to design and build better combat systems.

TABLE 4. DEVOPS CONCEPTS AND ASSOCIATED CHALLENGES

DevOps Concept	Challenges
Open Communication and Close Collaboration	• Rigid organizational hierarchy • Security requirements • Cultural inertia
Continuous Experimentation	• Statutory requirements • Rigid test processes • Rigid requirements generation process
Continuous Feedback	• Lack of infrastructure • Security requirements • Cultural inertia
Continuous Integration	• Cultural inertia • Rigid test processes • Rigid requirements generation process • Hardware requirements
Operational Flow	• Entrenched cultural practices • Rigid work processes • Rigid requirements generation process • Hardware requirements

The research used semistructured interviews to collect data from 11 SMEs. A limitation of the research is the small sample size compared to the large size and diversity of software development across program offices in the Navy and DoD. However, the findings agree with the challenges identified by the literature for commercial software systems (see Table 2). Our interviewees emphasized the security concerns and that cultural and organizational changes were necessary, although difficult to address in the DoD because of the regulations and entrenched culture. Knowing that the challenges resemble those found in commercial industry is useful because it suggests that the Navy can adapt and apply many of the industry approaches to overcome them. Understanding the obstacles facing adoption of DevOps is important for theoretical and practical reasons. First, this knowledge can help researchers bridge disconnected insights at the national and individual levels. Second, this knowledge can also help acquisition leaders develop plans and prepare interventions to support adoption of DevOps.

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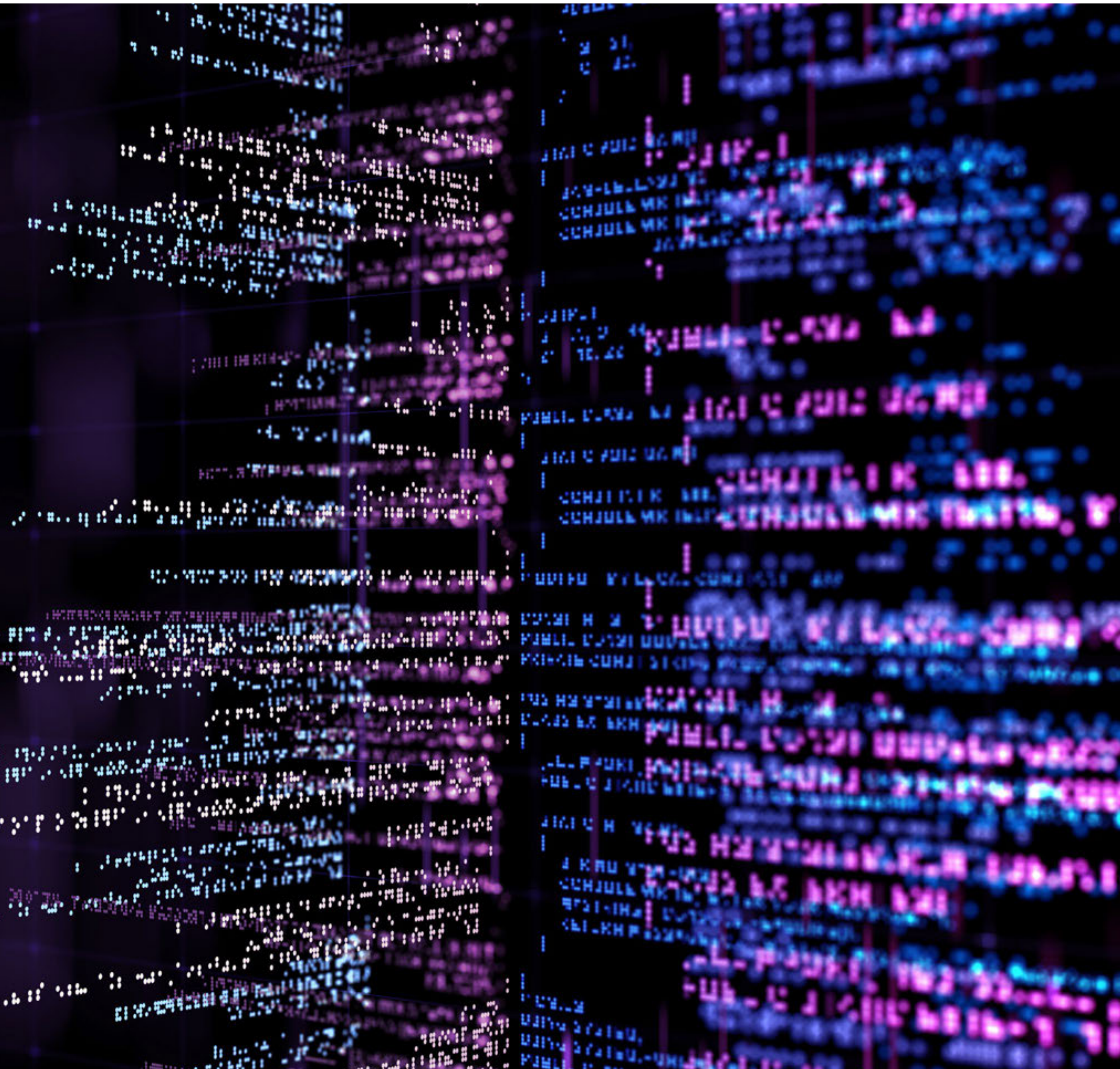

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OPTIMAL TALENT MANAGEMENT OF THE ACQUISITION WORKFORCE IN RESPONSE TO COVID-19: DYNAMIC PROGRAMMING APPROACH

Tom Ahn and Amilcar A. Menichini

As the economic impact of the COVID-19 pandemic lingers, with the speed of recovery still uncertain, the state of the civilian labor market will impact the public sector. Specifically, the relatively stable and insulated jobs in the Department of Defense (DoD) are expected to be perceived as more attractive for the near future. This implies changes in DoD worker quit behavior that present both a challenge and an opportunity for the DoD leadership in retaining high-quality, experienced talent. The authors use a unique panel dataset of DoD civilian acquisition workers and a dynamic programming approach to simulate the impact of the pandemic on employee retention rates under a variety of recovery scenarios. Their findings posit that workers will choose not to leave the DoD while the civilian sector suffers

Image designed by Nicole Brate

from the impact of the pandemic. This allows leadership to more easily retain experienced workers. However, once the civilian sector has recovered enough, these same workers quit at an accelerated rate, making gains in talent only temporary. These results imply that while the DoD can take short-run advantage of negative shocks to the civilian sector to retain and attract high-quality employees, long-run retention will be achieved through more fundamental reforms to personnel policy that make DoD jobs more attractive, no matter the state of the civilian labor market.

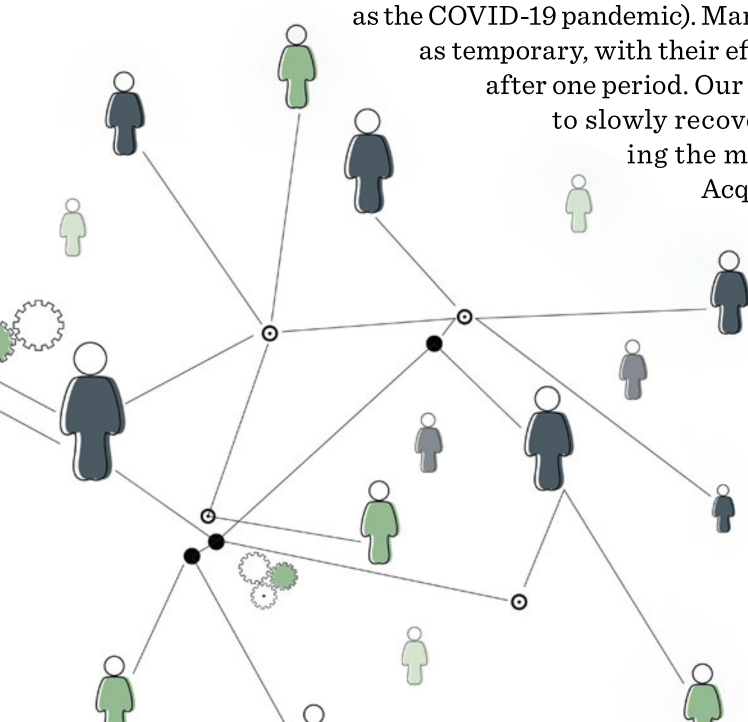
DOI: https://doi.org/10.22594/dau.21-871.29.01

Keywords: *Dynamic Retention Model, Dynamic Programming Model, Optimal Personnel Policy, Acquisition Workforce Retention*

The initial impact of the COVID-19 pandemic on the U.S. civilian labor market was massive, with the unemployment rate spiking to 15% in May 2020. While most world economies contracted in 2020, there is some consensus among economists of a relatively robust recovery in the near future, with average global economic growth projected to be about 5.5% in 2021 (International Monetary Fund, 2021). In the United States, the unemployment rate has already recovered partway since the nadir. However, the trajectory of recovery remains unclear, depending on a host of public health programs, government stimulus, and the macroeconomic environment.

While the civilian labor market has seen extraordinary swings in employment numbers, the government sector has been somewhat immune to the short-term effects of the pandemic. We examine the potential impacts of the gyrations and continuing uncertainty in the civilian labor market on the labor market decisions of public-sector employees, focusing on the civilian Defense Acquisition Workforce in the Department of Defense (DoD). Historically, senior DoD leadership has been concerned with losing qualified senior civilian workers to the private sector. However, the labor market impact of COVID-19 may present a pressing need to adjust personnel policy, as well as an opportunity to leverage the stability of DoD positions to compete against the draw of more lucrative salaries at private firms.

We solve a dynamic programming model of worker retention behavior, where long-lasting shocks in the civilian labor market are explicitly modeled. Retention behavior refers to the employee's decision to remain on the job to which currently assigned (i.e., Defense Acquisition Workforce, as defined in this article) from one period to the next. By shocks, we mean sudden, unpredictable events that affect the civilian labor market. Shocks in principle can be positive (such as unanticipated government stimulus) or negative (such as the COVID-19 pandemic). Many researchers model such shocks as temporary, with their effects on the economy dissipating after one period. Our model allows for negative shocks to slowly recover through time. After calibrating the model parameters to the Defense Acquisition Workforce using a unique panel administrative personnel dataset that tracks the civilian DoD labor force over the span of 30 years, we simulate civilian-side labor market shocks that correspond to economic recoveries of varying speeds and forecast the retention behavior of the workforce.



We find that a persistent negative shock to the civilian sector (plus insulation of the government/DoD labor market from the shock)—in our case, the COVID-19 pandemic—leads workers to devalue jobs in the private sector in the short-run and remain in the government sector for a longer period of time. Depending on the severity and persistence of the shock, it may take more than a decade for workers to return to valuing civilian jobs as they did before the pandemic. This relative increase in attractiveness of government jobs is only temporary, however, and workers accelerate their exit from the government sector into the private sector once the economic recovery is well underway. That is, the retention rate when the economy recovers turns out to be lower than the rate that would have prevailed had the global pandemic not occurred.

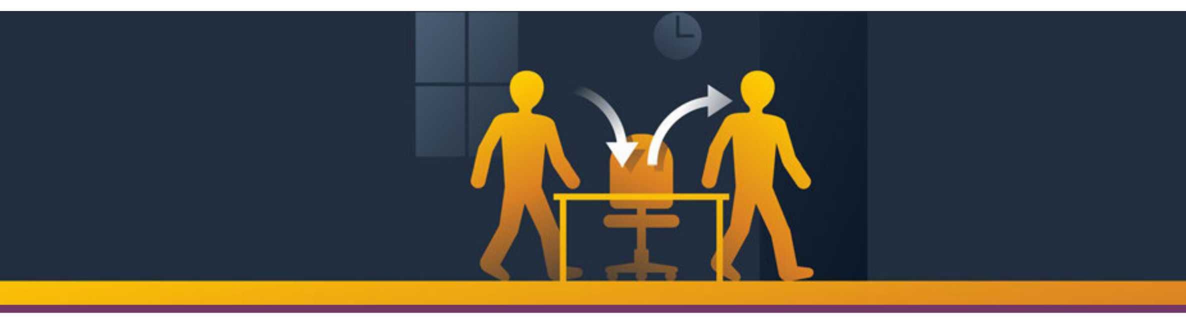
While the civilian labor market has seen extraordinary swings in employment numbers, the government sector has been somewhat immune to the short-term effects of the pandemic.

The sections that follow review the relevant literature and describe in more detail the labor market impact of COVID-19 on the private sector and the long-run career trajectories of the typical Defense Acquisition Workforce employee. Further discussion explains the dynamic programming model, describes the data, and calibrates the model parameters. Final discussion considers potential COVID-19 scenarios, projects behavior of the workforce under differing scenarios of economic recovery, and states our conclusions.

Literature Review

Employee retention has been studied extensively in the personnel economics literature. Most studies have been theoretic in nature or have focused on the private sector due to data availability (Barron et al., 2006; Fallick et al., 2006; Gibbons & Katz, 1991; Lazear, 1986; Wilson, 1969; among many others). One strand of the literature examines retention issues in the DoD, focusing on active-duty soldiers and officers at inflection points in their careers, such as the end of the first Service obligation or promotion (Goldberg, 2001; Warner, 1995). Others study the impact of reenlistment bonuses (Hattiangadi et al., 2004), civilian sector options (Fullerton, 2003), and nonmonetary job characteristics (Golding & Gregory, 2002).

Our article complements the literature on retention issues in the Defense Acquisition Workforce. Guo et al. (2014) and Ahn and Menichini (2021) investigated the demographic factors associated with higher Defense Acquisition Workforce employee retention, such as performance ratings and education. Focusing on retention strategies, Schwartz et al. (2016) analyzed the pay flexibilities authorized by Congress and the Office of Personnel Management to enhance retention of talented Defense Acquisition Workforce personnel. Alternatively, Kotzian (2009) proposed organizational culture and leadership style as effective strategies to increase retention in the long-run. In line with Kotzian, Jenkins (2009) suggested that, instead of monetary benefits, workplace satisfaction and organizational commitment should be the focus of the leadership to achieve highly qualified employee retention. Dobriansky (2009) noted the stability of government positions as a draw for workers compared to the private sector.



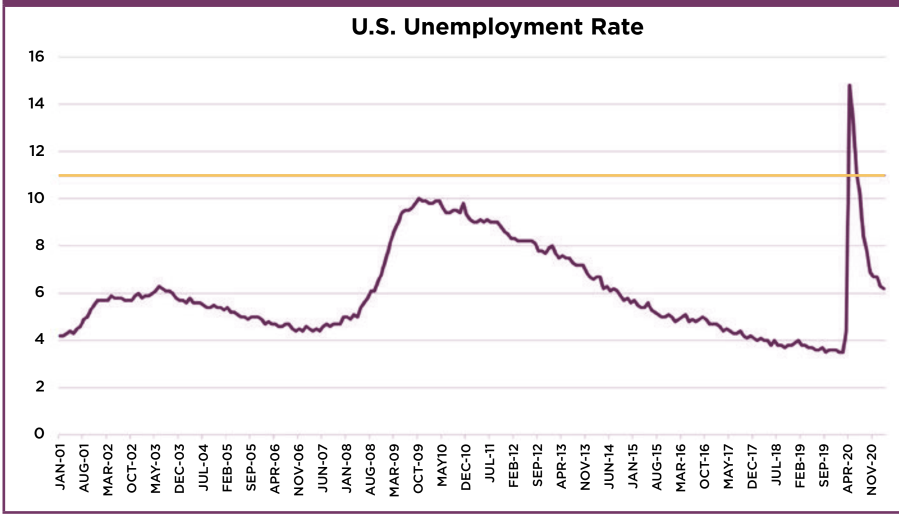
Our article is also related to the literature using the Dynamic Retention Model (DRM) to study employee stay/leave decisions in the government sector. For instance, Asch et al. (2013) used the DRM to analyze how policy changes affect retention decisions during the transition period between the old and the new regulations (e.g., impact of changes in retirement policy).

The Impact on Unemployment Arising from Covid-19

The short-run impact of COVID-19 has been extraordinary, with the nation's unemployment rate spiking to almost 15% from near historical lows (3.5%) in 2 months. As Figure 1 shows, even during the Great Recession, the nation's unemployment rate peaked at 10.6%. As a further reference, we added a yellow line in Figure 1 showing the previously recorded all-time high in monthly unemployment rate from the U.S. Bureau of Labor Statistics, which was about 11% at the end of 1982. The Congressional

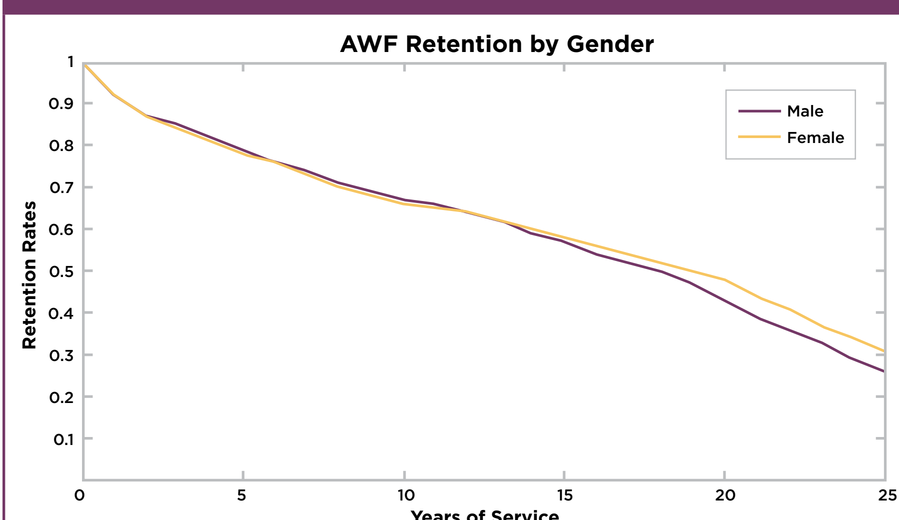
Budget Office (CBO) projects that the U.S. economy will grow 4.6% in 2021, after contracting 3.5% in 2020. These are significantly upwardly revised estimates from its report in July 2020, when the CBO projected a growth rate of 4%. Correspondingly, employment has recovered sharply since May 2020 (CBO, 2021)

FIGURE 1. CIVILIAN UNEMPLOYMENT RATE



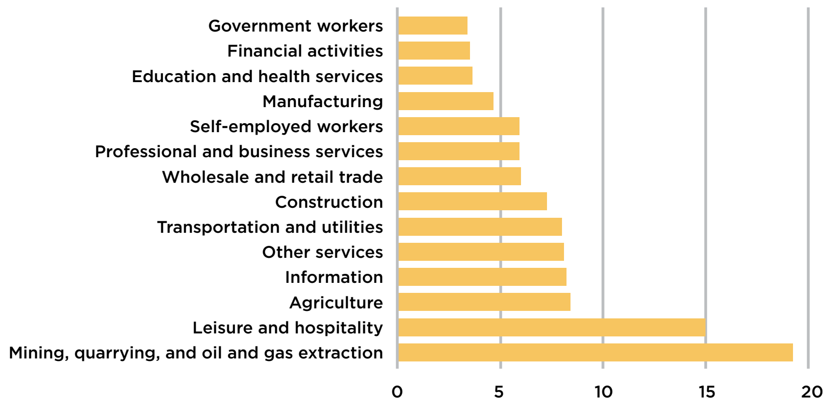
Note. Raw data from Bureau of Labor Statistics

FIGURE 2. CAREER TRAJECTORIES OF DOD AWF EMPLOYEES



Note. Adapted from Ahn and Menichini (2019).

FIGURE 3. UNEMPLOYMENT RATE BY SECTOR, NOVEMBER 2020



Note. Raw data from Bureau of Labor Statistics

However, it remains unclear when the economy can return to "business-as-usual" and how much vigor it will have on the rebound. Public health factors such as the efficacy of vaccines and their distribution, the spread of more infectious variants of COVID-19, and sustained use of masks and social distancing until herd immunity is reached, will all play a role. In addition, the recovery of the rest of the world; additional federal, state, and local fiscal stimuli; as well as permanent changes in the economy, such as expanded work-from-home and reconfiguration of global supply chains, may impact the private-sector labor market for years to come.

> **While job stability has always been a draw for the government sector, the state of the economy as well as the continuing uncertainty about the speed of economic recovery should make jobs in the DoD relatively much more attractive**

The impact of such changes to the private sector will inevitably affect the public sector, especially for the civilian workforce within the DoD. The combination of uncertainty in the private sector and a comparatively stable government sector is expected to alter their long-term career trajectories. Figure 2 shows the retention rate of Defense Acquisition Workforce workers, adapted from Ahn and Menichini (2019). The sample covers September 1987 to December 2018. Approximately 30% of workers leave the DoD after about 8 years of service. After approximately 25 years of experience, roughly three-quarters of employees have left. While it is undeniably true that some employee turnover is beneficial (for instance, to jettison low-quality or unmotivated employees and bring in fresh talent), DoD leadership has consistently expressed a desire to hold on to highly skilled and experienced civilian workers (e.g., Department of Navy, 2018).

While the shock of COVID-19 has been felt in almost every sector of the labor market, the government sector has notably been shielded from the worst of the impact. Figure 3 shows that, as of November 2020, government workers experienced an unemployment rate around 4%. This rate is lower than workers in the education and health services fields, who have received much wider media coverage of labor shortages due to the health risks from their proximity to the pandemic.

While job stability has always been a draw for the government sector, the state of the economy as well as the continuing uncertainty about the speed of economic recovery should make jobs in the DoD relatively much more attractive. Indeed, this argument parallels what has been known for a long time in military recruiting: demand for military jobs is countercyclical to the state of the civilian economy. With the backdrop of this large, negative, persistent, and unpredictable shock to the civilian labor market, we model the long-run labor market decisions of civilian DoD employees using a dynamic programming framework.

Model

In this section, we describe the different parts of the Dynamic Programming Model of employee retention that will be used to produce policy simulations.

We assume Defense Acquisition Workforce workers are rational decision makers who make career choices to maximize utility over their lifetime. The individual evaluates, at each decision point, all the costs and benefits involved in each possible choice, including pecuniary as well as nonpecuniary elements, which we describe in the following discussion. At the beginning of each period (i.e., 1 year in this article), the worker chooses between leaving the Defense Acquisition Workforce to continue a career in the private sector or remaining in the public sector one more period. In addition, given that we observe in our data that only about 6% of workers who leave the Defense Acquisition Workforce return at a later date, plus the difficulty in discerning why they left (and why they returned), we further assume that leaving the Defense Acquisition Workforce is an irreversible decision.

We next describe all the costs and benefits (including monetary and non-monetary elements) that the individual trades off in every decision point. We assume that the pecuniary components include:

- Defense Acquisition Workforce compensation, including basic pay, health insurance, locality adjustment, bonuses
- Compensation in the private sector

We also assume the Defense Acquisition Workforce employee is included in the Civil Service Retirement System (CSRS), and model public retirement accordingly. While our dataset contains employees from both the discontinued CSRS and the current Federal Employee Retirement System (FERS), we model the CSRS because more individuals belong to that system in our sample. For employees working in the private sector, we assume they are contributing to a 401(k) plan where the employer matches up to 10% of gross pay. As we note in the data section, the modal Defense Acquisition Workforce employee has a bachelor's degree or above and earns close to $100,000 at the highest paygrade attained. Workers with these characteristics in the civilian sector most often have employer matching 401(k) options.

The nonpecuniary components refer to the individual's taste or preference for a job in the Defense Acquisition Workforce versus a career in the private sector. These components attempt to capture the taste of those agents who prefer the higher predictability and stability of public sector employment, even at the cost of a lower salary compared to the private sector, and vice versa. To capture these relative preferences, we use taste parameters reflecting monetary-equivalent preferences for careers in the private versus the public sectors.

In particular, we use the following notation to construct the dynamic model:

- ${W_t}^m$ indicates compensation in the Defense Acquisition Workforce (including all pecuniary components) in period t
- ${W_t}^c$ denotes compensation in the private sector in period t
- ω^m is the public sector taste parameter, which captures the monetary-equivalent preference for a career in the Defense Acquisition Workforce
- ω^c is the private sector taste parameter, which captures the monetary-equivalent preference for a private sector career
- T denotes the labor time horizon (number of working periods before final retirement)
- $\beta = \frac{1}{1+r}$ is the discount factor, where r represents the subjective discount rate
- ε_t^m and ε_t^c are the random shocks affecting government and civilian jobs, respectively, in period t
- $E[.|\varepsilon_t - 1]$ indicates the expectation operator, given the shock in the previous period

Given that we observe in our data that only about 6% of workers who leave the Defense Acquisition Workforce return at a later date, plus the difficulty in discerning why they left (and why they returned), we further assume that leaving the Defense Acquisition Workforce is an irreversible decision.

The maximization problem faced by the Defense Acquisition Workforce worker can be described by the following set of equations:

$$V_t^L = W_t^c + \omega^c + \beta E[V_{t+1}^L | \varepsilon_t^c] + \varepsilon_t^c \quad (1)$$

$$V_t^S = W_t^m + \omega^m + \beta E[V_{t+1} | \varepsilon_t^c, \varepsilon_t^m] + \varepsilon_t^m\text{, and} \quad (2)$$

$$V_t = Max[V_t^L, V_t^S] \quad (3)$$

In these equations, superscript S denotes the agent's choice to continue working one more period in the Defense Acquisition Workforce (i.e., S = Stay). Alternatively, super-index L indicates the individual's choice to quit the Defense Acquisition Workforce job to continue a career in the private sector (i.e., L = Leave). Therefore, V_t^S denotes the (present) value of remaining in the public sector one more period, while V_t^L indicates the (present) value of switching to the private sector. Equation (3) implies that the individual will decide to be part of the Defense Acquisition Workforce force in every period in which $V_t^S > V_t^L$ and will leave the force as soon as the opposite is true. In economics terms, the value of leaving the Defense Acquisition Workforce, V_t^L, represents the opportunity cost of choosing to stay in the public sector one more period.

Regarding stochastic variables ε_t^m and ε_t^c, we assume they are independent and mean reverting over time (t dimension). The specification of the random shocks is the following:

$$\varepsilon_t^c = \mu_c + \rho_c \varepsilon_{t-1}^c + \tau_t^c, \quad \tau_t^c \sim N(0,\sigma_c^2) \tag{4}$$

$$\varepsilon_t^m = \mu_m + \rho_m \varepsilon_{t-1}^m + \tau_t^m, \quad \tau_t^m \sim N(0,\sigma_m^2)\text{, and} \tag{5}$$

$$\tau_t^c \text{ independent of } \tau_t^m \tag{6}$$

That is, the random shocks evolve independently of each other, oscillating around their own long-run (unconditional) mean over time. In the context of equations (1)–(3), these stochastic variables could be interpreted as sudden and unpredicted events impacting the civilian and private sector salaries (i.e., W_t^m and W_t^c, respectively) over time, stemming from, for instance, fluctuations in the business cycle. As we describe later, we use these random variables to introduce the COVID-19 shock. Ashenfelter and Card (1982) found that nominal wages are well represented by autoregressive models of order 1, also known as AR(1) processes. In this type of model, the forecast of the variable of interest is based on the current value of the variable. For instance, the prediction of nominal wages in the next period would be based on the current value of nominal wages. Over time, random variables following AR(1) processes oscillate around their long-run means. Accordingly, equations (4) and (5) define AR(1) representations for the random shocks. These AR(1) processes play an important role for our main results as they allow shocks to persist over time, that is, to gradually fade as time passes. As we explain in more detail later, we use parameter ρ to define the speed at which the economy (i.e., wages) recovers from a shock (e.g., from the COVID-19 outbreak). In terms of the optimization problem described in equations (1)–(3), random shocks ε_t^m and ε_t^c indicate state variables observed by the Defense Acquisition Workforce worker at the time of the decision.

Data Description and Model Calibration

In this section, we describe the Defense Acquisition Workforce sample as well as the selection and calibration of the parameter values necessary to implement the Dynamic Programming Model described previously. In the next section, we show those parameters provide a good approximation of the long-run labor market outcomes for the representative worker in the Defense Acquisition Workforce.

Data: The Acquisition Workforce

The Defense Acquisition Workforce comprises approximately 150,000 employees, covering the period September 1987–December 2018. Civilians make up about 90% of the workforce, while active-duty Service members make up the remaining 10%. The Defense Acquisition Workforce's mission is the "timely and cost-effective development and delivery of warfighting capabilities to America's combat forces" (DoD, 2015). The Defense Acquisition Workforce was responsible for overseeing the equipping and sustaining of the nation's military, spending over $1 trillion from FY 2016 to FY 2021. About 26% of the Defense Acquisition Workforce belongs to the engineering career field, followed by contracting at 19%. Historically, the Defense Acquisition Workforce was sharply reduced in size and capability during the 1990s. The DoD started to rebuild the Defense Acquisition Workforce in 2008 and increased it by approximately 50,000 employees over 13 years.

For this analysis, we restrict our sample to workers who were ever in the contracting, industrial property management, or purchasing fields. Our sample workers were born after January 1, 1950, but before December 31, 1980. Workers with birthdates outside this range are either too old, in that the environment in which they made their labor decisions may not reflect current jobs in the Defense Acquisition Workforce; or too young, in that these workers have not had time to make labor decisions that are pivotal to their careers. Restricting the sample nets us over 2 million worker-month records, with over 13,000 unique workers tracked through their careers. Table 1 presents some summary statistics for our sample.

TABLE 1. SUMMARY STATISTICS

Variables	Mean	Std. Dev.	Min	Max
Female	0.632			
Minority	0.278			
Disability	0.202			
Prior Military Service	0.619			
Has Bachelor's Degree	0.547			
Has Postgraduate Degree	0.332			
Gained Additional Education in AWF	0.441			
Career Length in AWF (in years)	12.0	(8.6)	0.1	25.8
Age at Entry	33.0	(8.2)	15	65
Age at Exit	48.2	(10.55)	20	68
Position Type: Professional	0.657			
(Ever Held) Technical	0.245			
Blue-Collar	0.018			
White-Collar	0.297			
Ever Rated Not Fully Satisfactory	0.575			
Highest Salary	95,143.67	(30,410.74)	27,397	189,600
Observations	13,590			

The workforce is predominantly white and female. Over half the workforce has a bachelor's degree or above. Compared to the civilian sector, careers in the Defense Acquisition Workforce are stable, with the average career length lasting well over a decade. This workforce is also highly paid, with the average employee earning almost $100,000 toward the end of their career. On average, workers in this sector begin their career at age 33, which indicates that the position in the Defense Acquisition Workforce is not their first job. In fact, a large number of these workers have prior military experience.

To rigorously assess the impact of the civilian sector on the attractiveness of the DoD position, every employee in the dataset must be "assigned" and can expect to earn a civilian wage. To accomplish this, we estimate a hedonic regression using the Outgoing Rotation Group (ORG) of the Current Population Survey (CPS). As this dataset contains a representative sample of workers in the United States, including, most importantly, those who are in the government sector, it is possible to make an apples-to-apples comparison with workers in the private sector. (See Ahn and Menichini [2021] for a detailed description.)

We run a hedonic regression using the individual socio-demographic characteristics, professional and education experience, and locality indicators from the ORG of the CPS, which broadly match the Defense Acquisition Workforce variables summarized in Table 1, to obtain predicted civilian and government sector wages. The difference in the wages across private and public sectors, conditioned on individual characteristics, defines the government sector "wage penalty."

Calibration Results

Before simulating the model described in equations (1)–(3), we define the parameter values, which we show in Table 2 and subsequently describe. We can observe in Table 2 that all parameter values, except compensation, are constant over the career of the Defense Acquisition Workforce employee.

TABLE 2. PARAMETER VALUES

Parameter	Value
W_t^m	1
W_t^c	1.1761
T	25
β	0.95
ω^m	1.2782
ω^c	1
μ_m	0
μ_c	0
ρ_m	0.90
ρ_c	0.90
σ_m	0.005
σ_c	0.005

As we described earlier, estimates from the hedonic regressions suggest that income in the private sector (i.e., W_t^c) is, on average, around 17.61% higher than in the Defense Acquisition Workforce (i.e., W_t^m) for individuals with similar characteristics. For this reason, after initially normalizing $W_t^m = 1$, we let $W_t^c = 1.1761$. We then add the income from the different retirement systems; thus, compensation changes over time. The data described earlier also show that the longest observed labor time horizon among all individuals is 25 years. For that reason, we let $T = 25$. The subjective discount factor is assumed to be 0.95, implying an interest rate of 5.26%, which is similar to the average 30-Year T-Bond Constant Maturity Rate reported by the Federal Reserve Bank of St. Louis for the period covered by the dataset.

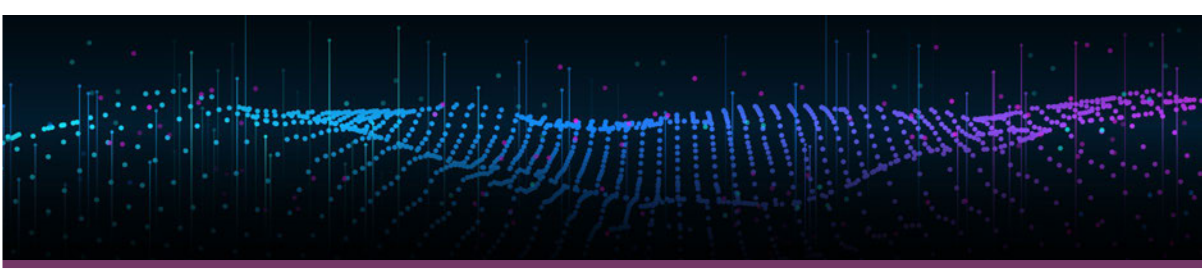
Regarding the taste parameters, we calibrated parameter ω^m so that the survival curve predicted by the model approximates the empirical survival curve as closely as possible via grid search (we show the graphical results of this calibration in the next section). In more technical terms, the calibration exercise searches for the value of ω^m that minimizes the summed squared distance between the points of the empirical Defense Acquisition Workforce survival curve and the points of the survival curve predicted by the model. As Table 2 displays, we normalize $\omega^c = 1$ and, from the calibration exercise, we obtain $\omega^m = 1.2782$. These values are similar to those estimated by Ahn and Menichini (2021), and imply that the representative Defense Acquisition Workforce employee prefers the Defense Acquisition Workforce over the private sector.

The remaining parameter values in Table 2 refer to the stochastic process of the random variables ε_t^m and ε_t^c. We follow Ashenfelter and Card (1982) to define the parameter values that govern the AR(1) processes of those terms. Accordingly, we let parameters μ_m and μ_c be equal to zero, we assume values of 0.005 for the standard deviation of the random shocks, σ_m and σ_c, and let the mean-reversion coefficients, ρ_m and ρ_c, be equal to 0.9. These values depict the historical behavior of the shocks. In particular, those observed values of the mean-reverting coefficients suggest that wages have a high level of persistence over time; thus, the effects of shocks require a long time to disappear.

Model Solution and Policy Simulations

In this section, we describe our policy simulations to forecast evolution in the behavior of the representative Defense Acquisition Workforce worker under a number of scenarios with differing speed rates of economic recovery from a large, abrupt, and unanticipated negative impact (i.e., COVID-19) to the private sector. This is a major systematic event that adversely affects all sectors of the economy, except for the public or government sector, which we assume keeps its employment constant (in fact, any future unanticipated national shock to the economy and/or public health that is concentrated mainly in the private sector can be expected to operate in a similar manner). The assumption that the government sector is not affected by the shock is consistent with the assumption of independent random shocks in equation (6).

Concisely, we introduce a large negative civilian shock at a point in time. Then, we allow the system to recover and converge back to the steady state. We start analyzing retention behavior assuming the economy recovers according to the empirical historical speed. However, given the observed recovery from the current pandemic seems to be, so far, much faster than normal, we also study the retention implications of different scenarios for the speed of recovery. We "control" the speed of recovery of the economy by setting the autoregressive term, ρ, which controls the velocity at which shocks gradually disappear over time.



While the private sector goes through its gyrations, at every period the representative Defense Acquisition Workforce agent in our model surveys the current state of the private sector, forecasts the evolution of the state of the economy, and makes the *ex ante* optimal decision to stay or leave the Defense Acquisition Workforce. We describe the simulation procedure in more detail next.

We solve the model described in equations (1)–(3) via backward induction. (See Rust [1987] for an empirical treatment.) That is, we start from the final period (i.e., $t = T = 25$) and decide whether to stay one more (final) period in the Defense Acquisition Workforce or to leave for the private sector. We then move one period backward (i.e., $t = 24$) and select to stay one more period or to leave the Defense Acquisition Workforce, considering the value from the optimal decision in period $T = 25$. We continue moving backward, deciding rationally in every period, until we reach the present period (i.e., $t = 0$). This solution characterizes the retention behavior of a representative Defense Acquisition Workforce employee in all possible states of the economy.

FIGURE 4. RETENTION BEHAVIOR

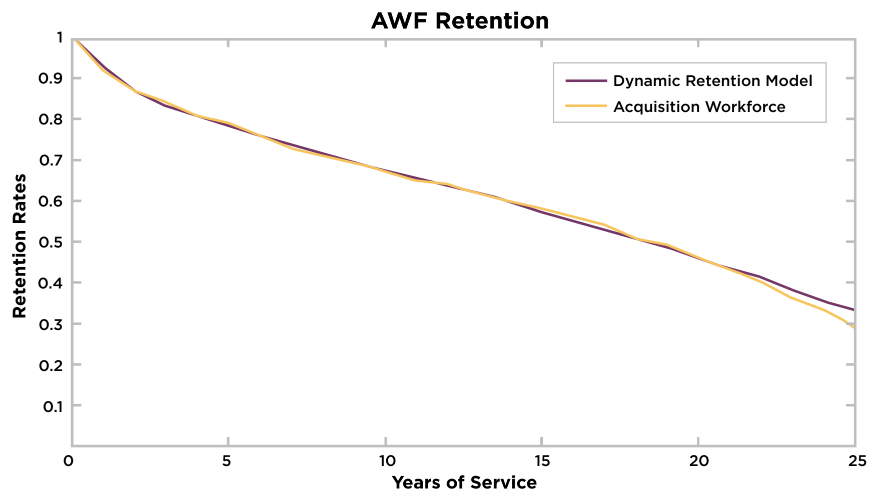
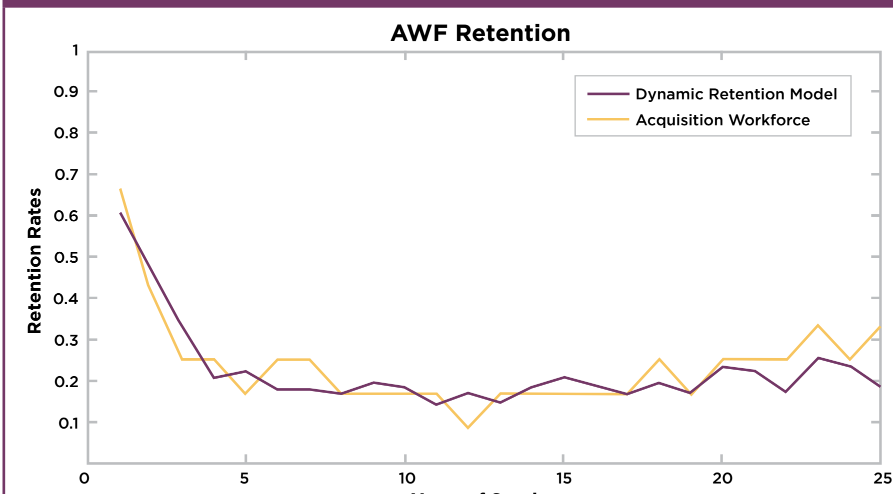


FIGURE 5. PROBABILITY OF LEAVING



We then stochastically simulate the model forward (i.e., over the 25 years of work) 100,000 times, which produces the stay/leave decisions of 100,000 employees in all possible different situations over the labor period. These simulations summarize the retention behavior of the representative employee, which we show in Figure 4. The figure exhibits the calibrated, model-predicted survival curve of the representative individual (purple line) and displays the cumulative probability of the worker staying in the Defense Acquisition Workforce after a certain period of time. For example, the figure suggests that the likelihood that the employee is still part of the Defense Acquisition Workforce after 10 years is about 65%. The figure also shows the empirical survival curve for the Defense Acquisition Workforce employees (yellow line) from the data described previously, suggesting that the calibrated model predicts actual behavior quite closely. While Figure 4 displays the retention behavior of a representative Defense Acquisition Workforce employee, each demographic group described in Table 1 would have its own survival curve.

Clearly, the historical coefficient implies it would easily take a decade or more to return to normality. However, a year after the appearance of the virus, the economy seems to be recovering much faster than suggested by historical terms.

Associated with the previous survival curves are the yearly, model-predicted probabilities of leaving the Defense Acquisition Workforce, which we show as the blue line in Figure 5. The retention rate is relatively high every year, as is shown by the fact that the likelihood of leaving is always below 10% per year, and below 5% in the great majority of years. In addition, the probability of leaving is high initially, and diminishes through time before increasing again toward the end of the individual's career. For instance, the probability that the employee departs from the Defense Acquisition Workforce in year 10 is around 2%. As before, we also show the empirical likelihood of leaving (yellow line) for comparison purposes.

We then proceed to shock the model with a large negative random draw on the civilian side (i.e., ε_t^c) at year 10. The shock is equivalent to 3 standard deviations below the mean and is intended to capture the large effect of the sudden appearance of COVID-19. In economic terms, given the calibration shown in Table 2, this shock could be interpreted as a roughly 1.5% reduction in the civilian salary, W_t^c, while the public sector salary, W_t^m, remains unchanged. The fact that the random shocks (both ε_t^m and ε_t^c) are mean reverting over time implies that the impact of the negative shock on the civilian salary gradually disappears as time passes. As mentioned before, the speed of return to the pre-shock state will depend on the mean-reversion coefficient, ρ.

FIGURE 6. EXPECTED IMPACT OF COVID-19 ON CIVILIAN SHOCK

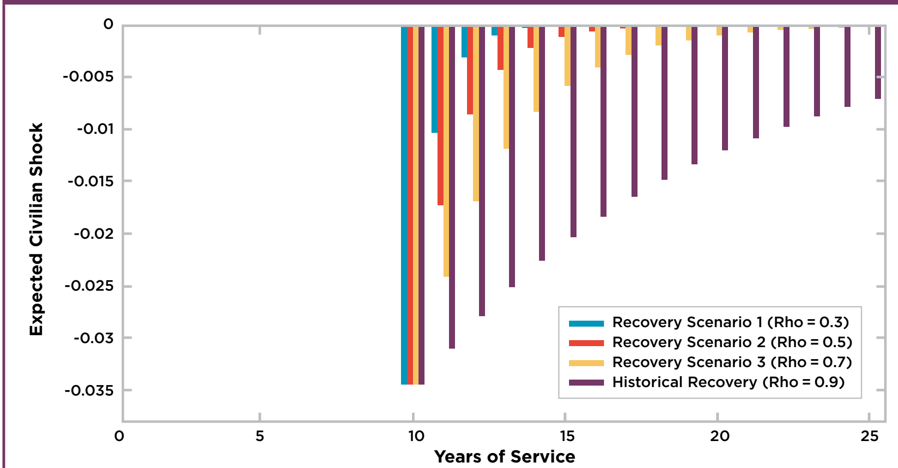
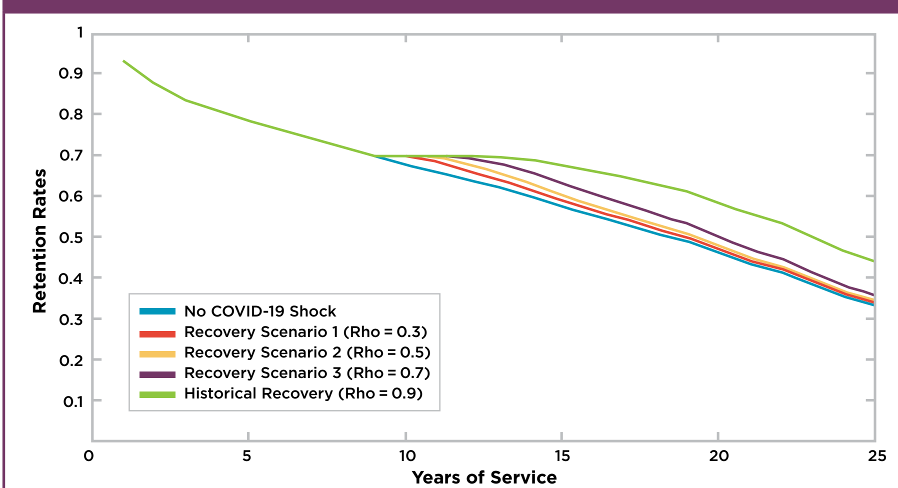


FIGURE 7. RETENTION IMPACT OF COVID-19

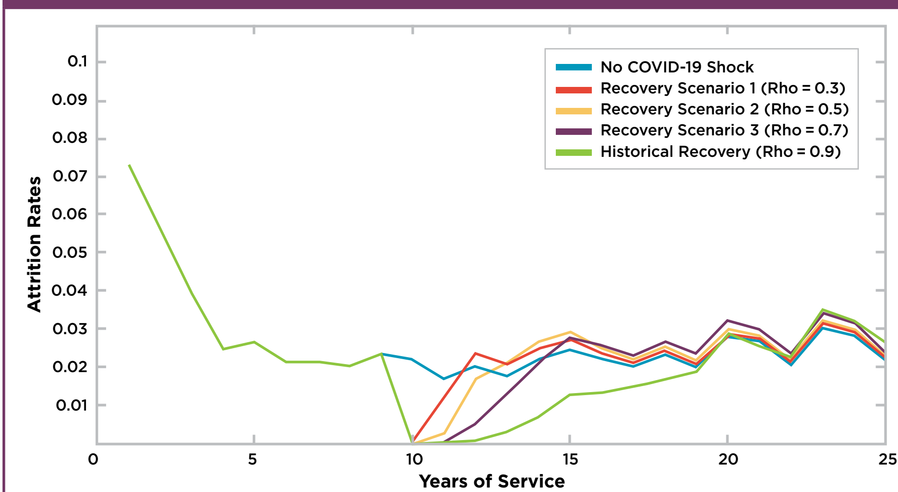


In Figure 6 we show, given the initial negative shock, how the shocks are expected to evolve over time for four different values of the coefficient of mean-reversion. The purple bars depict the historical case, which is based on the observed historical mean-reversion coefficient of $\rho = 0.9$. Clearly, the historical coefficient implies it would easily take a decade or more to return to normality. However, a year after the appearance of the virus, the economy seems to be recovering much faster than suggested by historical terms. We attempt to capture the faster rebound by reducing the coefficient of mean-reversion (i.e., via a quicker dissipation of the shock). Accordingly, we analyze three different scenarios featuring dissimilar speeds of recovery, all of which are faster than the historical speed. Scenario 1, with the blue bars and $\rho = 0.3$, represents the case of a relatively faster return to the pre-COVID economy. On the other hand, the yellow bars in scenario 3, with $\rho = 0.7$, reflect a slower recovery to normality as compared to scenario 1. In between are the red bars of scenario 2, showing an intermediate speed of recovery with $\rho = 0.5$. Even in the more optimistic recovery scenario 1, the effects of the large negative shock clearly remain in place for some years. While we acknowledge that the magnitude and persistence of the shocks are speculative, they are informed by very recent (and ongoing) research. Many scholars are currently attempting to forecast the long-run impact of COVID-19 on the economy. (See Petrosky-Nadeau and Valetta [2020], for an example of such ongoing research.)

The effect on retention behavior of the representative Defense Acquisition Workforce worker can be observed in Figure 7. The figure shows that, during the initial 10 years, the retention behavior is equivalent to the blue line in Figure 4. At year 10, the COVID-19 shock happens, and the retention behavior changes considerably. As mentioned before, we study the retention behavior in four different contexts. The green line shows the retention impact of the virus under historical terms (i.e., $\rho = 0.9$). The other lines depict the expected retention behavior for three faster rates of economic recovery (i.e., $\rho = 0.3$, $\rho = 0.5$, and $\rho = 0.7$ for recovery scenarios 1, 2, and 3, respectively). In all cases, a kink and sudden flattening of the curve is evident, suggesting that individuals stay longer in the Defense Acquisition Workforce in an attempt to avoid the sharp negative effect of the virus shock on the civilian labor market. Depending on the speed of recovery, it might take a substantial amount of time for the employee to return to the pre-shock retention behavior. For instance, in the historical case it takes around 10 years for the representative employee to return to the previrus retention behavior, while in scenarios 1, 2, and 3, the return to normality takes roughly 2, 3, and 5 years, respectively. These long-lasting effects on retention behavior have important implications for the hiring policies of the public sector.

It is worth noting that the time required to return to the "original" behavior specified previously does *not* mean that all workers will choose to delay leaving the Defense Acquisition Workforce by several years due to the impact of COVID-19. Instead, all employees will process the negative shock in the civilian economy as making the Defense Acquisition Workforce job more attractive. Until the shock fully dissipates, the DoD position will be more attractive than if no global pandemic had occurred. However, given the substantial wage premium in the civilian sector, the pandemic shock does not need to completely disappear before workers who were planning to move to the civilian sector resume their plans.

FIGURE 8. LIKELIHOOD OF LEAVING WITH COVID-19



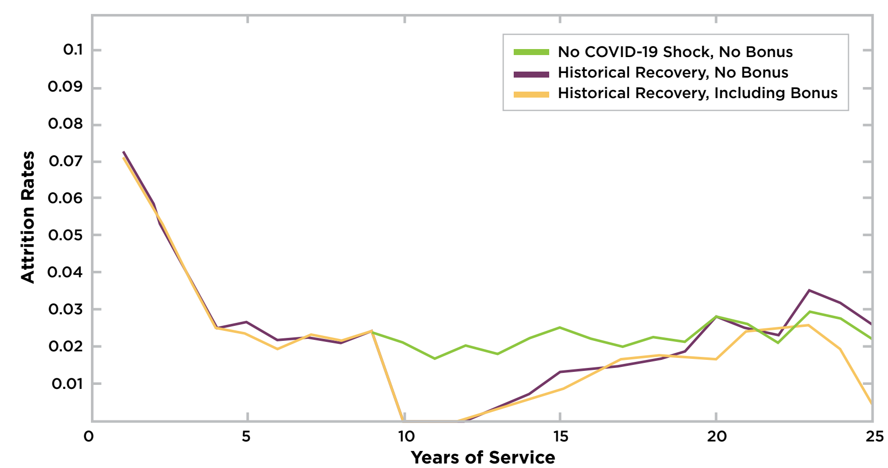
To complement the analysis of the return to the pre-COVID context, we present Figure 8. The figure shows the model-predicted yearly probabilities of leaving the Defense Acquisition Workforce for the four different values of parameter ρ. The green line shows the retention behavior in the historical recovery scenario, confirming that it takes around 10 years to return to the pre-COVID retention behavior (the latter is represented by the no-COVID-19-shock blue line). The red, yellow, and purple lines, reflecting faster speeds of economic rebound, suggest that around 2, 3, and 5 years, respectively, are required to eliminate the effects of the COVID-19 shock on retention. In all four scenarios, the likelihood of leaving the Defense Acquisition Workforce goes roughly to zero in the year of the shock, and then slowly starts to return to the no-shock levels as time passes and the effects of the shock dissipate.

Given the substantial wage premium in the civilian sector, the pandemic shock does not need to completely disappear before workers who were planning to move to the civilian sector resume their plans.

It is also important to note that, after the return to normality, the probability of leaving is higher in the slower recovery scenarios and lower in the faster rebound scenarios. More generally, after the COVID-19 shock dissipates, in all cases with shock, the likelihood of leaving is higher than in the no-shock case, with that probability increasing in parameter ρ. Indeed, the slower the recovery from the pandemic (i.e., higher ρ value), the larger the magnitude of exit probability after the recovery. This outcome suggests that, as more people decide to stay longer in the Defense Acquisition Workforce during the pandemic, when the economy returns to normal the pent-up demand to leave for the private sector is expressed as a higher likelihood of leaving in the later years. This implies an opportunity as well as a problem for the Defense Acquisition Workforce leadership. While a slower recovery may induce more employees to stay longer, it cannot be a permanent solution to retain high-ability workers. A higher ρ will result in a much sharper exit of workers from the Defense Acquisition Workforce once the civilian economy recovers.

To retain these workers, fundamental (and traditional) personnel policy reforms will be required. For example, a pay increase or expansion of benefits before the civilian sector fully recovers may permanently induce senior workers to remain in the Defense Acquisition Workforce. Similarly, a one-time retention bonus, set far enough into the future when the civilian economy is back to normal, could prevent that exit.

FIGURE 9. PROBABILITY OF LEAVING WITH COVID-19 AND A BONUS AT 25 YEARS OF SERVICE



Although a full analysis of the available policy reforms is outside the scope of this article, we show with more detail one particular way by which that expected long-term effect could be counteracted. In particular, we analyze the effect of a one-time bonus on the probability of leaving the Defense Acquisition Workforce when the economy returns to normality. We assume the bonus is equivalent to 25% of the individual's monthly salary and is paid at year-of-service 25 (with the virus shock occurring at year 10). Figure 9 shows the main results of this exercise. The expected bonus has a fairly small effect on employee retention in the early- and mid-career years, as the retention rates are almost equivalent with and without the bonus.

However, as expected, the effect of the bonus is more visible in the final years of the employee's career, when the economy has fully recovered from the COVID-19 shock. Without the bonus (purple line), the likelihood of leaving is substantially higher than with the bonus (yellow line), suggesting that, indeed, a bonus would induce experienced employees to stay longer in the Defense Acquisition Workforce after the recovery. Finally, the bonus is just one of the tools available to the Defense Acquisition Workforce to affect individual retention behavior (for instance, salary raises would be another useful tool).

Conclusions

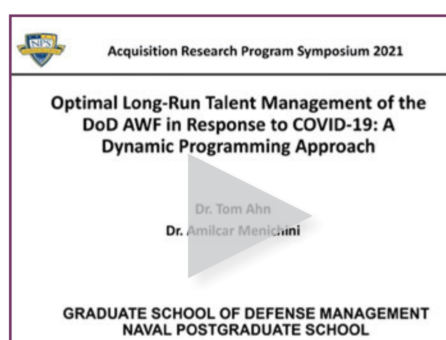
As of early 2021, the overall unemployment rate in the United States stands at 6.2%—an 8-percentage point decrease in just 8 months from the worst unemployment rate in almost 90 years arising from the COVID-19 global pandemic, yet still almost double the unemployment rate from just one year ago. While the recovery has been as dramatic as the decline, the future remains very much in doubt. For example, in December 2020, payrolls shrank by 140,000. Outlook has considerably brightened since, but whiplash in the long-run forecast of economic recovery itself adds uncertainty to future labor market prospects in the civilian market.

> **Forward-looking leaders should regard these simulation results not as predictions of the future, but as guides to help set personnel policies that are flexible and adjustable, and even take advantage of gyrations in the civilian economy.**

In this environment, we analyzed the potential impact of the economic recovery on the labor market trajectory of the Defense Acquisition Workforce. The contrast in stability of jobs in the government compared to the private sector should increase the attractiveness of DoD jobs, especially if the recovery proves to be slow or unpredictable. We built and calibrated a dynamic programming model of employee retention behavior, analyzed the impact of a negative persistent shock to the civilian sector, and simulated different recovery paths.

The larger the magnitude of the negative shock to the civilian economy, the more our results show that government positions become more attractive; while the slower the economic recovery, the more highly employees may value government positions compared to the prepandemic period for several years.

While this environment can increase retention of the average worker from the Defense Acquisition Workforce, leadership should understand that, eventually, recovery of the civilian sector will push down the relative desirability of government jobs. This may lead to a speedy exodus of many senior-level workers who were being held back due to economic uncertainty. Personnel planning without considering the temporary increment in retention at the beginning of the shock may lead to overhiring, especially at the junior-levels. Conversely, short-sighted reductions in hiring due to the initial impacts of the negative shock may lead to a hollowing out of the workforce, once the shock impact wanes. In addition, as the economy recovers, there may be fundamental structural changes to the labor market that remain, changing the valuation of both government and private sector jobs in unpredictable ways. Forward-looking leaders should regard these simulation results not as predictions of the future, but as guides to help set personnel policies that are flexible and adjustable, and even take advantage of gyrations in the civilian economy.



SCAN TO WATCH

Learn more about this article by watching Dr. Tom Ahn and Dr. Amilcar Menichini's presentation, *Optimal Long-Run Talent Management of the DoD AWF in Response to COVID-19.*

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Author Biographies

Dr. Tom Ahn

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is an Associate Professor in the Graduate School of Defense Management at the Naval Postgraduate School. Before joining the Naval Postgraduate School, he studied to attain his PhD in Finance from the University of Arizona. Dr. Menichini has published in *The Financial Review*, *Review of Quantitative Finance and Accounting*, and *Southern Economic Journal*.

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PROFESSIONAL READING LIST

The Defense Acquisition Professional Reading List is intended to enrich the knowledge and understanding of the civilian, military, contractor, and industrial workforce who participate in the entire defense acquisition enterprise. These book recommendations are designed to complement the education and training vital to developing essential competencies and skills of the acquisition workforce. Each issue of the *Defense Acquisition Research Journal* will include one or more reviews of suggested books, with more available on our website: http://dau.edu/library.

We encourage our readers to submit book reviews they believe should be required reading for the defense acquisition professional. The books themselves should be in print or generally available to a wide audience; address subjects and themes that have broad applicability to defense acquisition professionals; and provide context for the reader, not prescriptive practices. Book reviews should be 450 words or fewer, describe the book and its major ideas, and explain its relevance to defense acquisition. Please send your reviews to the managing editor, *Defense Acquisition Research Journal* at DefenseARJ@dau.edu.

Featured Book

Logistics Engineering and Management (Sixth Edition)

Author: Benjamin S. Blanchard

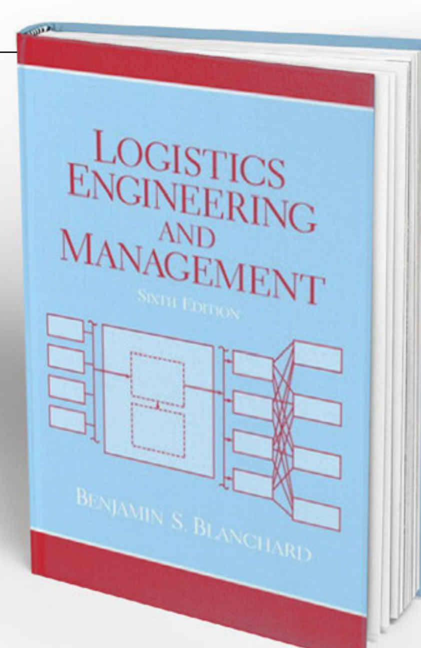
Publisher: Prentice Hall

Copyright Date: 2003

Hard/Softcover/Digital: Hardcover, 576 pages

ISBN-13: 9780131429154

Reviewed by: Shawn Harrison



Review:

Nearing its third decade in print, Blanchard's *Logistics Engineering and Management* continues to serve as an invaluable desk reference for the Defense Acquisition Workforce. When the book was first published, the author reflected on the state of DoD acquisition, including long procurement cycles and increased acquisition and sustainment costs as the burning platform to provide more emphasis on logistics early in the system life cycle. Fast-forward to today, and while DoD has made strides in several areas of acquisition reform, timely delivery of relevant capability to the warfighter at affordable cost remains a persistent challenge. Proper logistics planning, states Blanchard, is the key to effective and economical system support.

The book includes 11 chapters broadly organized into three parts: (1) definitions and principles; (2) life cycle logistics from requirements definition through fielding; and (3) logistics (or product support, in today's parlance) organization and planning. While its subject matter will likely appeal most to life cycle logisticians and engineering and technical management professionals, it will also interest to other Defense Acquisition Workforce members, including DoD program managers, business and financial managers, cost estimators, contracting specialists, and test and evaluation professionals.

In addition to a thorough treatment of the 12 DoD Integrated Product Support (IPS) Elements (minus Product Support Management and with some "legacy" terminology), Blanchard addresses reliability and maintainability, availability, functional analysis and requirements allocation, test and evaluation, production, system operational support, modifications, cost estimating, and a variety of related life cycle management topics. The eight appendices include detailed procedures on cost analyses, maintenance task analysis, logistics analytical models, a design review checklist, and various mathematical tables such as interest rate factors for cost estimating and normal distributions for predictive analysis.

Throughout, Blanchard includes many useful formulas and diagrams to facilitate understanding of key principles and concepts such as reliability, sparing, inventory cycles, cost estimating methodologies, schedule network analysis, and maintenance planning. These are interwoven effectively into the narrative text, which is highly readable even for nontechnical personnel. The text also includes numerous questions and problems at the end of each chapter, but alas no "answer key" (though third-party sources are available). Many problems have direct relevance to today's acquisition challenges, and the questions are highly useful for reflection, with many fitting nicely with DAU's "20 Questions Every Product Support Manager (PSM) Should Be Prepared to Answer." Examples of DoD-relevant systems (aircraft, wheeled vehicles, support and test equipment, etc.) are also sprinkled throughout the text to enhance learning and application. Finally, readers may find the computer-aided design (CAD) section (which was state-of-the-art at the time of initial publication) a bit rudimentary, but in light of the 2018 DoD Digital Engineering Strategy, Blanchard presciently reminds us the logistician must be able to adapt to rapidly changing design processes, including becoming conversant in, and able to, leverage model viewers and related analytical tools. In summary, *Logistics Engineering and Management* remains a highly useful and relevant text for today's Defense Acquisition Workforce professional.

Note: The Fourth edition (1992) may be the last "U.S." edition.

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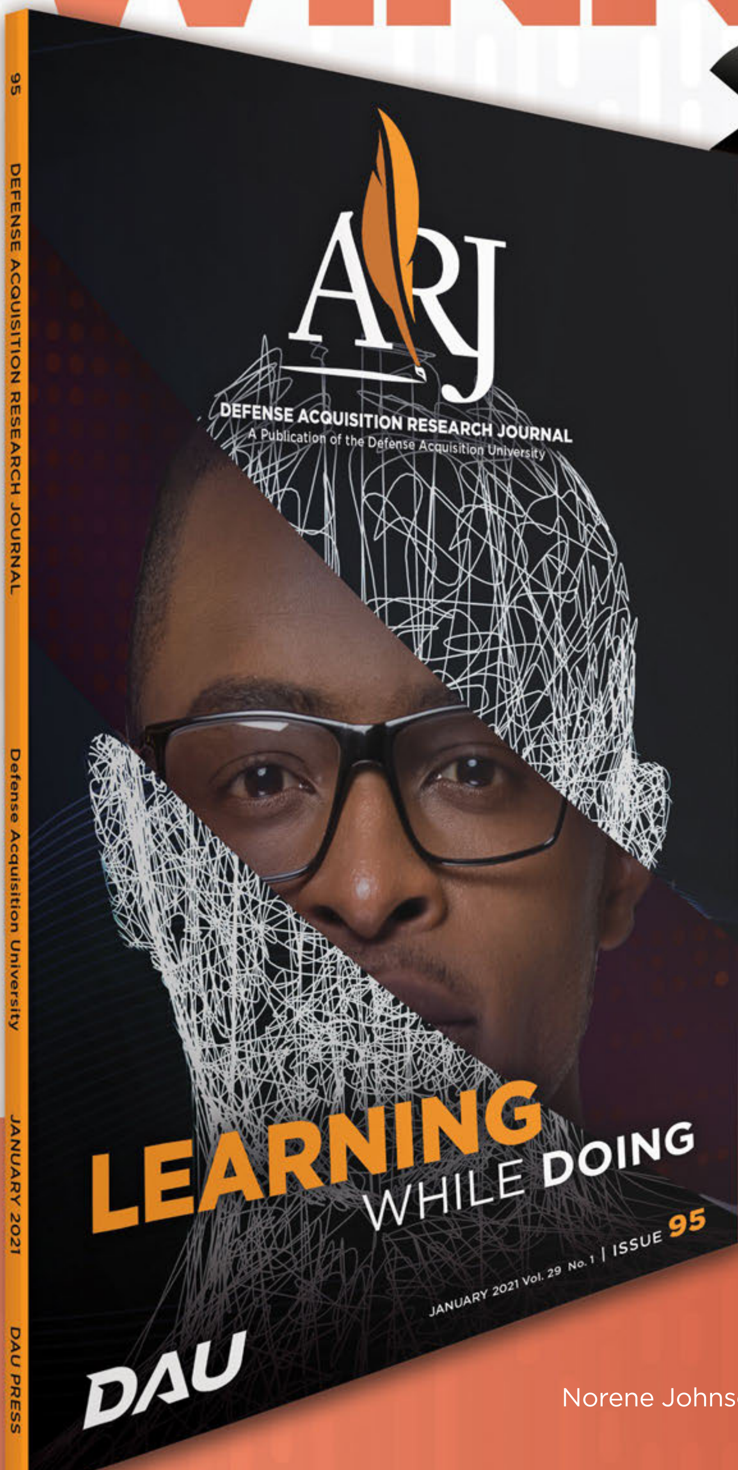

Norene Johnson, Emily Beliles, and Nicole Brate

DAU Press

Fort Belvoir, VA

Current Research Resources in DEFENSE ACQUISITION

Public Procurement and COVID-19

Each issue of the *Defense Acquisition Research Journal* will bring to the attention of the defense acquisition community a topic of current research, which has been undertaken by the DAU Virtual Research Library team in collaboration with DAU's Director of Research. Both government civilian and military Defense Acquisition Workforce readers will be able to access papers publicly and from licensed resources on the DAU Virtual Research Library Website: https://dau.libguides.com/daukr.

Nongovernment Defense Acquisition Workforce readers should be able to use their local knowledge management centers/libraries to download, borrow, or obtain copies. We regret that DAU cannot furnish downloads or copies.

Defense Acquisition Research Journal readers are encouraged to submit proposed topics for future research by the DAU Virtual Research Library team. Please send your suggestion with a short write-up (less than 100 words) explaining the topic's relevance to current defense acquisition to: Managing Editor, *Defense Acquisition Research Journal*, DefenseARJ@dau.edu.

COVID-19 Contracting: Opportunities to Improve Practices to Assess Prospective Vendors and Capture Lessons Learned

Marie A. Mak

Summary:

In response to COVID-19, agencies awarded contracts for goods and services to vendors from a range of industries and with varying levels of federal contracting experience, but some vendors have been unable to deliver under those contracts. The Coronavirus Aid, Relief, and Economic Security (CARES) Act included a provision for the Government Accountability Office (GAO) to review COVID-19-related federal contracting under the Act. This report addresses (a) COVID-19 contract obligations and characteristics of vendors, (b) contracting challenges, including agency assessments of vendors, and (c) whether lessons learned efforts reflect those challenges. GAO analyzed federal procurement data on agencies' reported COVID-19 contract obligations through May 31, 2021.

APA Citation:

Mak, M. A. (2021). *COVID-19 contracting: Opportunities to improve practices to assess prospective vendors and capture lessons learned* (Report No. GAO-21-528). https://www.gao.gov/products/gao-21-528

Observations: Fiscal Year 2020 COVID-19 Federal Contracting

Brooke Holmes

Summary:

The Pandemic Response Accountability Committee (PRAC)'s objective was to review pandemic-related federal contracts and identify first-time contractors and contracts awarded without competitive bidding. The author found that first-time federal contractors received $4.4 billion worth of pandemic contracts in Fiscal Year 2020 and that $128 million was deobligated from contracts with first-time federal contractors during the same period. Additionally, the author identified the four most common flexibilities applied to justify limited competition were: (a) urgency, (b) only one source, (c) simplified acquisition procedures, and (d) authorized by statute. Of these, the author found that 11% of noncompetitive contracts used the "only one responsible source" authority, which is defined to be used when supplies and services are available from only one source in certain conditions. A limited sample revealed that 10 of 14 contracts either shouldn't have selected that authority or had data entry errors within the Federal Procurement Data System.

APA Citation:

Holmes, B. (2021). *Observations: Fiscal Year 2020 COVID-19 federal contracting*. Pandemic Response Accountability Committee. https://www.pandemicoversight.gov/media/file/first-time-federal-contractors

Special Report on Best Practices and Lessons Learned for DoD Contracting Officials in the Pandemic Environment

Theresa S. Hull

Summary:

This special report provides best practices and lessons learned identified in audit reports related to disaster responses. Of the 52 reports, 36 were focused on oversight of contracting related to disaster response activities. The author analyzed the audit reports and determined several

best practices and lessons learned related to contracting from the DoD's previous disaster relief responses. In addition, this special report provides potential procurement fraud schemes and tips to avoid potential fraudulent activity.

APA Citation:

Hull, T. S. (2020). *Special report on best practices and lessons learned for DoD contracting officials in the pandemic environment* (Report No. DODIG-2020-085). Department of Defense Inspector General. https://media.defense.gov/2020/Jun/23/2002319892/-1/-1/1/DODIG-2020-085.PDF

"Crisis Is a Great Accelerant": How the U.S. Navy is Drastically Improving Its Contracting Performance Under COVID-19

Anne Laurent

Summary:

By the end of April 2020, as the COVID-19 pandemic was forcing most of the United States to shut down and federal agencies had begun teleworking en masse, the U.S. Navy reported that it was beating its 2019 contracting performance by double digits. By April 2020, the Navy had already put $94.6 billion on contract—33% more than the $74 billion it had obligated at the same time in 2019. Not only that, but the increase came with a 19% decrease in contract actions. What's more, the contracting acceleration came as more than 95% of Navy contracting personnel were teleworking, according to James "Hondo" Geurts, Assistant Secretary of the Navy (Research, Development, and Acquisition). Deputy Assistant Secretary of the Navy Karen Fenstermacher and her team also reached out directly to most of the supplier base, listening to their stories with an ear toward how the Navy could help—which helped the Navy to determine which companies to prioritize and how to align opportunities for stimulus funding.

APA Citation:

Laurent, A. (2020). "Crisis is a great accelerant": How the U.S. Navy is drastically improving its contracting performance under COVID-19. *Contract Management, 60*(7), 34–39. https://www.proquest.com/magazines/crisis-is-great-accelerant-how-u-s-navy/docview/2458773491/se-2?accountid=40390

COVID-19: Lessons Learned in Public Procurement. Time for a New Normal?

Laurence Folliot Lallion and Christopher R. Yukins

Summary:

The COVID-19 crisis upended markets and assumptions in public procurement, and posed an almost existential threat to traditional procurement systems. Seismic changes occurred in economic relationships—governments were no longer monopsonists, government officials failed as economic intermediaries between suppliers and the public, and supplies that were traditionally treated as private (such as medical equipment) suddenly became "public" goods in demand worldwide. Traditional trade rules were rendered irrelevant, as the goal was no longer simply to open individual procurements but rather to open borders to intense global demand. Although the disruption was revolutionary, ironically the solution is to return to first principles of transparency and integrity to preserve governments' fragile legitimacy in a crisis.

APA Citation:

Lallion, L. F. and Yukins, C. R. (2020). COVID-19: Lessons learned in public procurement. Time for a new normal? *Concurrences, 1*(3), 46–58. https://scholarship.law.gwu.edu/cgi/viewcontent.cgi?article=2763&context=faculty_publications

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Norene Johnson, Emily Beliles, and Nicole Brate

DAU Press

Fort Belvoir, VA

Defense ARJ Guidelines **FOR CONTRIBUTORS**

The *Defense Acquisition Research Journal (ARJ)* is a scholarly peer-reviewed journal published by DAU. All submissions receive a double-blind review to ensure impartial evaluation.

IN GENERAL

We welcome submissions describing original research or case histories from anyone involved in the defense acquisition process. Defense acquisition is broadly defined as any actions, processes, or techniques relevant to as the conceptualization, initiation, design, development, testing, contracting, production, deployment, logistics support, modification, and disposal of weapons and other systems, supplies, or services needed for a nation's defense and security, or intended for use to support military missions.

Research involves the creation of new knowledge. This generally requires either original analysis of material from primary sources, including program documents, policy papers, memoranda, surveys, interviews, etc.; or analysis of new data collected by the researcher. Articles are characterized by a systematic inquiry into a subject to establish facts or test theories that have implications for the development of acquisition policy and/or process.

The *Defense ARJ* also welcomes case history submissions from anyone involved in the defense acquisition process. Case histories differ from case studies, which are primarily intended for classroom and pedagogical use. Case histories must be based on defense acquisition programs or efforts. Cases from all acquisition career fields and/or phases of the acquisition life cycle will be considered. They may be decision-based, descriptive, or explanatory in nature. Cases must be sufficiently focused and complete (i.e., not open-ended like classroom case studies) with relevant analysis and conclusions. All cases must be factual and authentic. Fictional cases will not be considered.

We encourage prospective writers to coauthor, adding depth to manuscripts. We recommend that junior researchers select a mentor who has been previously published or has expertise in the manuscript's subject. Authors should

be familiar with the style and format of previous *Defense ARJs* and adhere to the use of endnotes versus footnotes, formatting of reference lists, and the use of designated style guides. It is also the responsibility of the corresponding author to furnish any required government agency/employer clearances with each submission.

MANUSCRIPTS

Manuscripts should reflect research of empirically supported experience in one or more of the areas of acquisition discussed above. The *Defense ARJ* is a scholarly research journal and as such does not publish position papers, essays, or other writings not supported by research firmly based in empirical data. Authors should clearly state in their submission whether they are submitting a research article or a case history. The requirements for each are outlined below.

Research Articles

Empirical research findings are based on acquired knowledge and experience versus results founded on theory and belief. Critical characteristics of empirical research articles:

- clearly state the question,
- define the research methodology,
- describe the research instruments (e.g., program documentation, surveys, interviews),
- describe the limitations of the research (e.g., access to data, sample size),
- summarize protocols to protect human subjects (e.g., in surveys and interviews), if applicable,

- ensure results are clearly described, both quantitatively and qualitatively,
- determine if results are generalizable to the defense acquisition community
- determine if the study can be replicated, and
- discuss suggestions for future research (if applicable).

Research articles may be published either in print and online, or as a Web-only version. Articles that are 5,000 words or fewer (excluding abstracts, references, and endnotes) will be considered for print as well as Web publication. Articles between 5,000 and 10,000 words will be considered for Web only publication, with a two sentence summary included in the print version of the *Defense ARJ*. In no case should article submissions exceed 10,000 words.

Case Histories

Care should be taken not to disclose any personally identifiable information regarding research participants or organizations involved unless written consent has been obtained. If names of the involved organization and participants are changed for confidentiality, this should be highlighted in an endnote. Authors are required to state in writing that they have complied with APA ethical standards. A copy of the APA Ethical Principles may be obtained at http://www.apa.org/ethics/.

All case histories, if accepted, will receive a double-blind review as do all manuscripts submitted to the *Defense ARJ*.

Each case history should contain the following components:

- Introduction
- Background
- Characters
- Situation/problem
- Analysis
- Conclusions
- References

Book Reviews

Defense ARJ readers are encouraged to submit book reviews they believe should be required reading for the defense acquisition professional. The reviews should be 500 words or fewer describing the book and its major ideas, and explaining why it is relevant to defense acquisition. In general, book reviews should reflect specific in-depth knowledge and understanding that is uniquely applicable to the acquisition and life cycle of large complex defense systems and services. Please include the title, ISBN number, and all necessary identifying information for the book that you are reviewing as well as your current title or position for the byline.

Audience and Writing Style

The readers of the *Defense ARJ* are primarily practitioners within the defense acquisition community. Authors should therefore strive to demonstrate, clearly and concisely, how their work affects this community. At the same time, do not take an overly scholarly approach in either content or language.

Format

Please submit your manuscript according to the submissions guidelines below, with references in APA format (author date-page number form of citation) as outlined in the latest edition of the *Publication Manual of the American Psychological Association.* References should include Digital Object Identifier (DOI) numbers when available. The author(s) should not use automatic reference/bibliography fields in text or references as they can be error-prone. Any fields should be converted to static text before submission, and the document should be stripped of any outline formatting. All headings should conform to APA style. For all other style questions, please refer to the latest edition of the *Chicago Manual of Style.*

Contributors are encouraged to seek the advice of a reference librarian in completing citation of government documents because standard formulas of citations may provide incomplete information in reference to government works. Helpful guidance is also available in *The Complete Guide to Citing Government Information Resources: A Manual for Writers and Librarians* (Garner & Smith, 1993), Bethesda, MD: Congressional Information Service.

The author (or corresponding author in cases of multiple authors) should attach a cover letter to the manuscript that provides all of the authors' names, mailing and e-mail addresses, as well as telephone numbers. The letter should verify that (1) the submission is an original product of the author(s); (2) all the named authors materially contributed to the research and writing of the paper; (3) the submission has not been previously published in another journal (monographs and conference proceedings serve as exceptions to this policy and are eligible for consideration for publication in the *Defense ARJ*); (4) it is not under consideration by another journal for publication. If the manuscript is a case history, the author must state that they have complied with APA ethical standards in conducting their work. A copy of the APA Ethical Principles may be obtained at http://www.apa.

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All manuscript submissions should include the following:

- Completed submission checklist

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- Cover letter containing the complete mailing address, e-mail address, and telephone number for each author
- Biographical sketch for each author (70 words or fewer)
- Headshot for each author saved as a 300 dpi (dots per inch) high resolution JPEG or Tiff file no smaller than 5x7 inches with a plain background in business dress for men (shirt, tie, and jacket) and business appropriate attire for women. All active duty military should submit headshots in Class A uniforms. Please note: low-resolution images from Web, PowerPoint, or Word will not be accepted due to low image quality.
- One copy of the typed manuscript, including:
    - Title (12 words or fewer)
    - Abstract (150 to 250 words)
    - Two sentence summary
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- Figures and tables saved as separate individual files and appropriately labeled
- Links to any supporting videos, lectures, interviews, or presentations to be shared in our digital publication.

The manuscript should be submitted in Microsoft Word (please do not send PDFs), double-spaced Times New Roman, 12-point font size (5,000 words or fewer for the printed edition and 10,000 words or fewer for online-only content excluding abstracts, figures, tables, and references).

Figures or tables should not be inserted or embedded into the text, but submitted as separate files in the original software format in which they were created. For additional information on the preparation of figures or tables, refer to the Scientific Illustration Committee, 1988, Illustrating Science: Standards for Publication, Bethesda, MD: Council of Biology Editors, Inc. Restructure briefing charts and slides to look similar to those in previous issues of the *Defense ARJ*.

All forms are available at our website: www.dau.edu/library/arj. Submissions should be sent electronically, as appropriately labeled files, to the *Defense ARJ* managing editor at: DefenseARJ@dau.edu.

Defense ARJ
PRINT SCHEDULE

The *Defense ARJ* is published in quarterly theme editions.

All submissions are due by the first day of the month.
See print schedule below.

Author Deadline	Issue
July	January
October	April
January	July
April	October

In most cases, the author will be notified that the submission has been received within 48 hours of its arrival. Following an initial review, submissions will be referred to peer reviewers and for subsequent consideration by the Executive Editor, ***Defense ARJ***.

Contributors may direct their questions to the Managing Editor, *Defense ARJ*, at the address shown below, or by calling 703-805-4655, or via email at DefenseARJ@dau.edu.

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- Be asked to speak at a conference or symposium.

We welcome submissions from anyone involved with or interested in the defense acquisition process—the conceptualization, innovation, initiation, design, testing, contracting, production, deployment, logistics support, modification, and disposal of weapons and other systems, supplies, or services (including construction) needed by the DoD, or intended for use to support military missions.

If you are interested, contact the *Defense ARJ* managing editor ***(DefenseARJ@dau.edu)*** and provide contact information and a brief description of your article. Please visit the *Defense ARJ* Submissions page at ***https://www.dau.edu/library/arj/p/Defense-ARJ-Submissions***.

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Defense Acquisition University
Attn DAU Press (Defense ARJ)
9820 Belvoir Road, Suite 3
Fort Belvoir, VA 22060-5565

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We would like to express our appreciation to all of the subject matter experts who volunteered to participate in the *Defense Acquisition Research Journal* peer review process. The assistance of these individuals provided impartial evaluation of the articles published during the 2021 print year. We would also like to acknowledge those referees who wished to remain anonymous. Your continued support is greatly appreciated, and we look forward to working with many of you again in print year 2022.

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