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Adapting TO THE ~~COVID~~ CHALLENGE

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ARTICLE LIST

Assessing Workforce Perceptions of Productivity and Success After 730 Days of Distributed Operations in Response to COVID-19
Glenn Tolentino, John Wood, and Shane Riley

Proactive Obsolescence Management Methods for C5ISR Systems: Insights from Practitioners
Matthew D. Chellin and Erika E. Miller

Adoption of Model-Based Systems Engineering in Traditional DoD Systems
Capt. Patrick Assef, USAF, and Lt. Col. Jeremy Geiger, USAF

ARJ EXTRA

The Defense Acquisition Professional Reading List

Start with No: The Negotiating Tools that the Pros Don't Want You to Know
Written by by Jim Camp and reviewed by John Krieger

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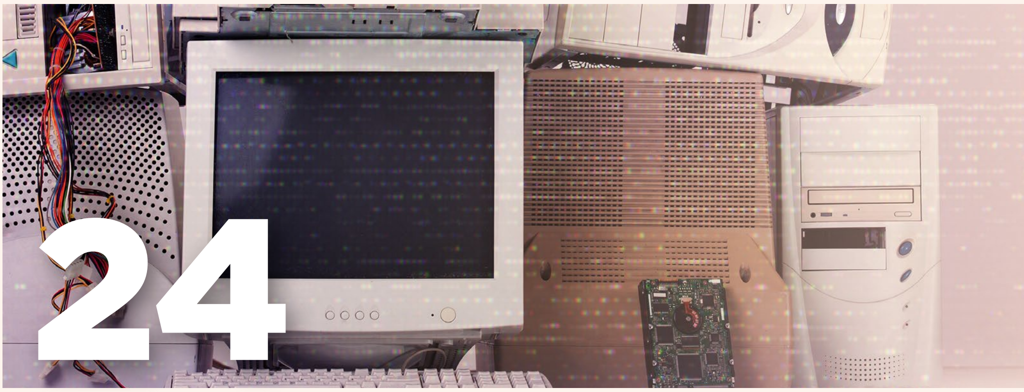
Assessing Workforce Perceptions of Productivity and Success After 730 Days of Distributed Operations in Response to COVID-19

Glenn Tolentino, John Wood, and Shane Riley

A U.S. Department of Defense workforce, with minimum telework experience, was directed to fully transition to a virtual, distributed, and maximum telework posture because of the COVID-19 pandemic crisis. This study evaluates the workforce's perceived effects of maximum telework after 730 days in the areas of personnel productivity and project success.



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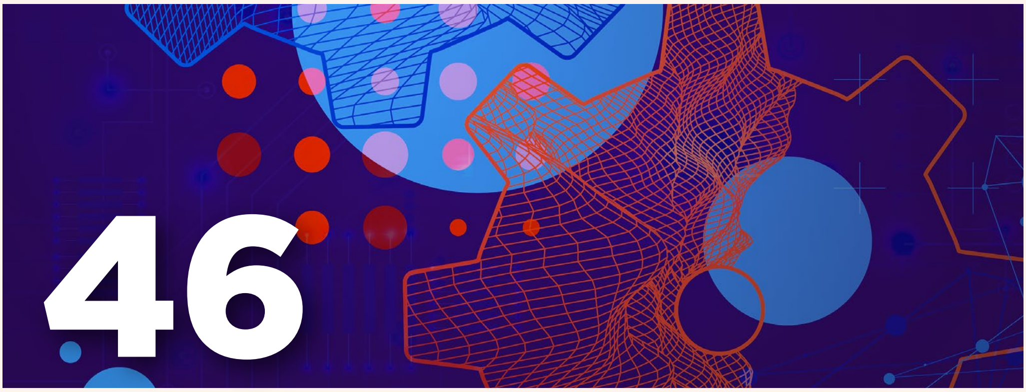
Proactive Obsolescence Management Methods for C5ISR Systems: Insights from Practitioners

Matthew D. Chellin and Erika E. Miller

Obsolescence adversely affects a system's cost, schedule, performance, and readiness. The purpose of this article is to offer the defense acquisition community key insights from practitioners and preliminary approaches to assist with proactive obsolescence mitigation.



Adoption of Model-Based Systems Engineering in Traditional DoD Systems

Capt. Patrick Assef, USAF, and Lt. Col. Jeremy Geiger, USAF

This research captures the efforts and resources required to transition an existing, DoD document-based system of systems (SoS) to Model-Based Systems Engineering (MBSE). It provides information for program offices to determine whether a transition to MBSE methods is the right choice for their existing system or system upgrade.

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Recognition of Reviewers 2022

We would like to express our appreciation to all of the subject matter experts who volunteered to participate in the *Defense ARJ* peer review process.

FROM THE CHAIRMAN AND EXECUTIVE EDITOR

Dr. Larrie D. Ferreiro

The theme for this issue is "Adapting to the COVID Challenge." Since early 2020, the globe has been in the grip of the COVID-19 pandemic that, as of this writing, has diminished but by no means completely disappeared. The three articles in this issue describe the evolution in management, engineering, and workforce practices that were already in motion when COVID-19 became widespread, but which were accelerated as a result of the pandemic.

The first paper, "Assessing Workforce Perceptions of Productivity and Success After 730 Days of Distributed Operations in Response to COVID-19," by Glenn Tolentino, John Wood, and Shane Riley, analyzes the reactions of the Defense Acquisition Workforce to the telework revolution. Using the Naval Information Warfare Center Pacific as the case history, the authors show how an organization with minimum telework experience was able to fully transition to a virtual, distributed, and maximum telework posture, while the majority of its workforce continued performing its duties in a virtual and secure distributed environment.

The second paper, "Proactive Obsolescence Management Methods for C5ISR Systems: Insights from Practitioners," by Matthew D. Chellin and Erika E. Miller, looks at the importance of keeping long-lived systems running effectively, given worldwide manufacturing and material shortages occurring in the aftermath of the COVID-19 pandemic and the current (as of this writing) Russo-Ukrainian War. The article synthesizes insights from the experiences of government and industry practitioners in mitigating systems obsolescence, using a preliminary proactive obsolescence management model, risk mitigation framework, and metrics.

The third paper, by Patrick Assef and Jeremy Geiger, titled "Adoption of Model-Based Systems Engineering in Traditional DoD Systems," is concerned with de-emphasizing a centralized, office- and document-based physical approach and transitioning to a digitized Model-Based Systems Engineering (MBSE) paradigm, which can facilitate the functioning of a virtual, distributed engineering workforce. The authors assess the time and resources needed for this transition as a benchmark for other defense program managers.

This issue's Current Research Resources in Defense Acquisition focuses on Acquisition Strategy.

The featured work in the Defense Acquisition Reading List book review is *Start with No: The Negotiating Tools that the Pros Don't Want You to Know,* by Jim Camp, reviewed by John Krieger.

We are deeply saddened to learn of the passing of Dr. John Ronald Fox of the Harvard Business School. Ron was a longtime friend and editorial board member of the *Defense ARJ.* His contributions will be greatly missed.

Dr. Steven Fasko has left the Editorial Board. We thank him for his service.

We welcome Dr. Georgella McRae to the Editorial Board.

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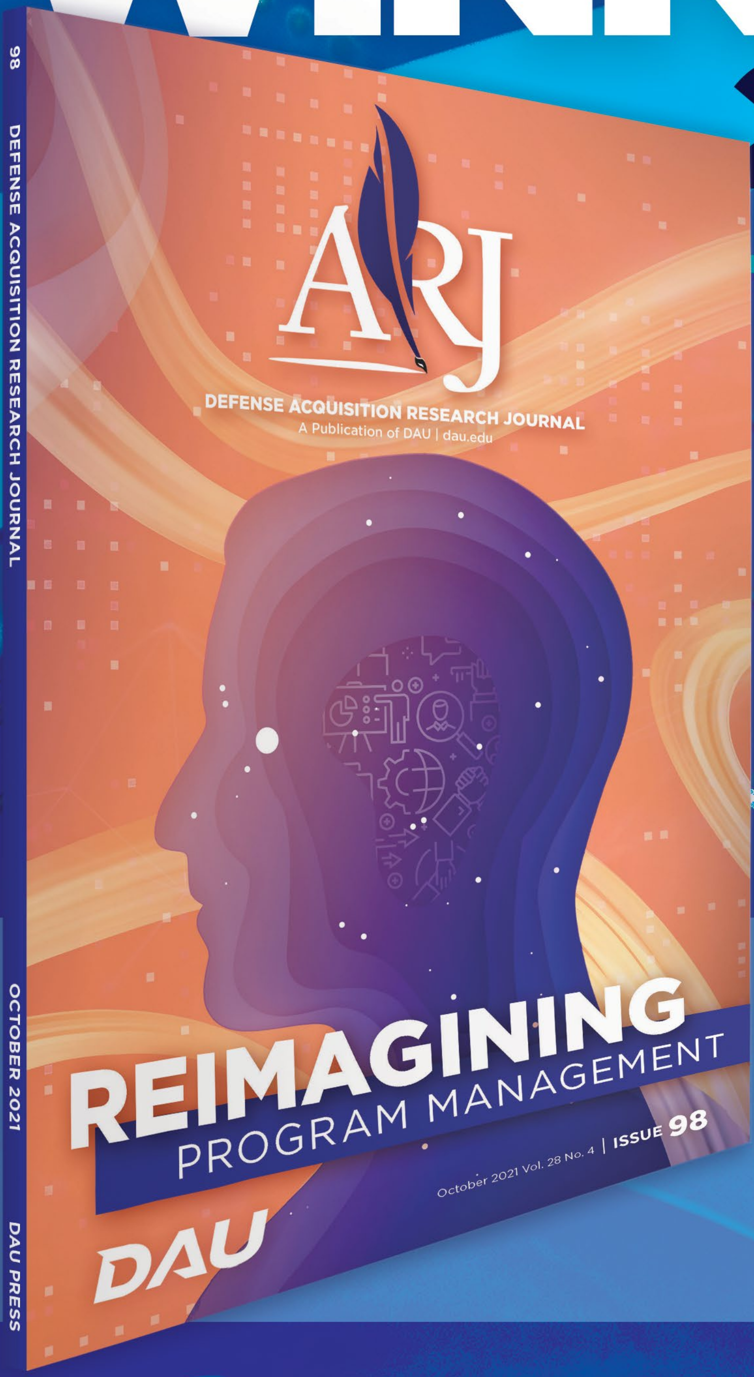

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DAU CENTER FOR DEFENSE ACQUISITION

Research Agenda 2023

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

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

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

Affordability and Cost Growth

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

- Recent acquisition studies have noted the vast number of programs and projects that don't make it through the acquisition system and are subsequently 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, such as percentage of revenue devoted to IR&D and collaboration with academia. How do they vary by industry sector—in particular, those associated with defense acquisition?
- What means are there (or can be developed) to measure the ROI for DoD-reimbursed IR&D versus directly funded defense R&D?
- What incentive structures will motivate industry to focus on and fund disruptive technologies?
- What impact has IR&D had on the development of disruptive technologies?

Competition

Measuring the effects of competition

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

Strategic competition

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

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

Effects of industrial base

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

Competitive contracting

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

Improve DoD outreach for technology and products from global markets

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

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

Comparative studies

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

Cybersecurity

General questions

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

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

Costs associated with cybersecurity

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

Acquisition of Services

Metrics

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

Industrial base

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

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

Industry practices

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

Make/Buy

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

Category management/strategic sourcing

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

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

Contract management/efficacy

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

Policy

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

Administrative Processes

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

Human Capital of Acquisition Workforce

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

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

Defense Business Systems

Organizational structure and culture in support of Agile software development methodologies

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

Defense Acquisition and Society

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

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

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Image designed by Nicole Brate

Glenn Tolentino, John Wood, and Shane Riley

During the midst of the Coronavirus Disease 2019 (COVID-19) pandemic, a large Navy Working Capital Funded (NWCF) government laboratory, Naval Information Warfare Center (NIWC) Pacific, transitioned from a traditional onsite/physical daily operational presence to a distributed, virtual, maximum telework posture. In short, unless NIWC Pacific's leadership directed that performance of a specific, approved tasking required that it take place at a particular physical workplace location, the laboratory workforce was directed to telework from a safe location while practicing social distancing.

To this extent, a majority of the workforce for NIWC Pacific's programs and projects continued performing their duties in a virtual and secure distributed environment. In addition, the Office of Personnel Management telework policy provided new guidance to give personnel adequate direction, including telework eligibility, agreement, definition, and types of telework arrangements.

This new norm certainly raised a number of questions and considerations for the organization as a whole related to the effectiveness of the workforce while under a maximum telework mandate. As a result, the authors distributed two surveys to a subset of the workforce in the early days of the pandemic to assess the perceived work effectiveness of the organization. After 730 calendar days of remote operation by the workforce, the authors initiated this study as a third inquiry, with the goal of understanding the long-term impact of distributed telework on productivity and effectiveness within a department of 900 employees.

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Keywords: *telework, pandemic, COVID-19, productivity, distributed and virtual operations*

ASSESSING WORKFORCE PERCEPTIONS OF Productivity and Success AFTER 730 DAYS OF Distributed Operations IN RESPONSE TO COVID-19

Naval Information Warfare Center (NIWC) Pacific is a critical subcomponent of the U.S. Department of the Navy (DoN), responsible for performing research, development, test, and evaluation (RDT&E). Additionally, NIWC Pacific provides deployment and sustainment of command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems; cyber systems; and space systems that support Warfighters around the world (NIWC Pacific, n.d.).

NIWC Pacific has a major presence in California, Hawaii, Guam, and Japan. The workforce consists of about 5,000 highly educated (200+ PhD/JD and over 1,500 MS degrees), diverse professionals focused in the areas of science and technology, engineering, and acquisition and management (NIWC Pacific, n.d.). The NIWC Pacific workforce in San Diego, California, is complemented by one of the largest concentrations of active-duty military personnel stationed in close proximity to a naval laboratory, which prepares NIWC Pacific to readily address operational challenges during war, peace, and humanitarian and other world crises.

Historically, Department of Defense (DoD) agencies were criticized for the pace at which they adapt and transform to change in nontactical campaigns (e.g., policy and culture) (Pomerleau, 2016). While this might be historically true in some cases, this was not the case during the COVID-19 pandemic at NIWC Pacific. Traditionally, an organization where onsite operations were the norm with minimum telework operations, NIWC Pacific immediately established a maximum telework order where more than 85% of all personnel transitioned their onsite work environment to their virtual home office. Within one week after the Office of Personnel Management (OPM, 2020) issued its maximum telework guidance (based on Office of Management and Budget [OMB] Guidance M-20-15), NIWC Pacific leadership estimated Continuity of Operations status was more than 90% personnel offsite, while remaining mission-essential personnel continued working onsite.

The authors performed the initial study shortly after the distributed operations (telework) guidance was instituted, which subsequently demonstrated a positive impact on workforce productivity and project success (Tolentino et al., 2021). After 2 years, NIWC Pacific continues to maintain an operational status with 80–90% of personnel working offsite. The initial study also provides "the extension of the literature on teleworking during COVID-19, by exploring situation and individual factors that influence the indicators of adjustment to telework, that is, perceived work productivity, job performance, and satisfaction" (Mihalca et al., 2021, p. 632). The initial study was also backed by an OPM article stating, "The 2021 OPM Federal Employee Viewpoint Survey demonstrates the continued resilience of the workforce through a second year of unprecedented challenges, and positive perspectives on the workforce capabilities to deliver results" (OPM, 2022, Key Statistics section). However, the workforce has now been performing maximum telework operations for an extended time, which begs the question from an organizational standpoint, whether or not NIWC Pacific has been able to maintain productivity and its ability to deliver cutting-edge technology to the end-user community. In studying how the current workforce—as of March 2022—has been operating in a distributed environment over time, this follow-on study continues to examine the same questions, based on the study, that were initially considered. First, how has maximum telework affected workforce productivity? Second, how has maximum telework affected project success?

> **The NIWC Pacific workforce in San Diego, California, is complemented by one of the largest concentrations of active-duty military personnel stationed in close proximity to a naval laboratory, which prepares NIWC Pacific to readily address operational challenges during war, peace, and humanitarian and world crises.**

Research Framework

In support of this study, the authors developed a research framework to illustrate and conceptualize the structure of the research plan (Figure 1). The framework provided a structure in addressing the basis of the problem and the approach to accomplishing the research (Maxwell, 2012). Using this framework, they developed survey questions by identifying key themes and concepts central to the core research questions. Objectives were defined along with the survey questions, which addressed these themes and objectives. Next, the data were collected and synthesized to verify whether the data addressed the problem statement. Finally, the results were published.

The researchers used this framework during all phases of the research study (Phases 1–3), along with the underlying methodologies for collecting and analyzing the data (Figure 2). Phase 1 of the research focused on a single project, while Phase 2 focused on multiple projects. The results of those two surveys were previously published (Tolentino et al., 2021). Phase 3, which is the focus of this article, expanded the sample environment to a department level, thus increasing the number of workforce personnel as well as the number of projects.

FIGURE 1. MAXIMUM TELEWORK RESEARCH FRAMEWORK

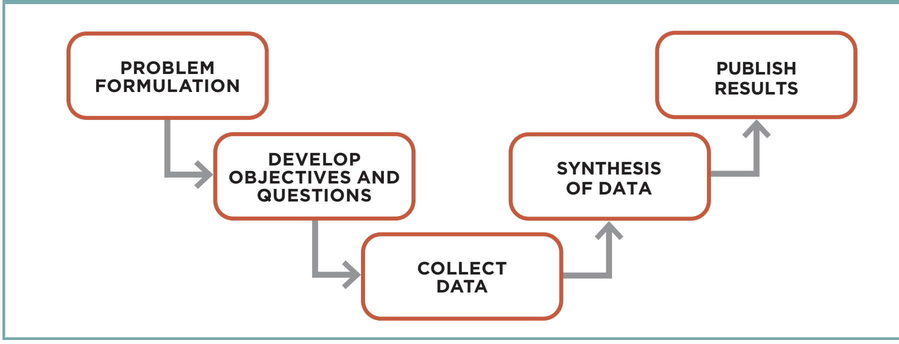


FIGURE 2. STUDY IN THREE PHASES

	Phase 1	Phase 2	Phase 3
No. of Projects	1	14	120
No. of Personnel	~100	~136	~900
Personnel Category	Government and Contractor Support	Government Only	Government Only
Published Results	*Tolentino et al., 2021*	*Tolentino et al., 2021*	*This Article*

Research Framework Focus—Phase 3 (Department)

After 730 days into maximum telework, since the telework guidance was first published in March 2020, the researchers expanded the scope of the survey participants to the NIWC Pacific Command & Control and Enterprise Engineering (C2E2) Department level, consisting of a large number of projects (120+) and personnel (900+). At NIWC Pacific, on average, a department consists of three to five divisions, each of which encompasses diverse technical leadership teams and support elements enabling the execution of multiple projects (NIWC Pacific, n.d.). While Phase 1 of this study targeted a single project and Phase 2 focused on a single division, the researchers felt that expanding the study to a larger number of projects within a department, including the associated support and leadership roles, would help confirm whether or not distributed operations in the form of maximum telework has been an effective means to support the Warfighters. Therefore, similar survey questions from the previous phases were posed to the department organization on how productive the workforce is and how successful the projects are while operating under maximum telework.

In assessing the department workforce in this study, the same methodology previously utilized in Phases 1–2 was also utilized in Phase 3. The survey provided a method for easily and efficiently collecting data across a broad scope of the department workforce. The survey contained both multiple choice and open-ended questions. In this study, some of the questions make use of the 4-point Likert scale to get a specific non-neutral response and avoid neutral options that allow participants to move on without giving careful thought to the question (Hopper, 2016b; McLeod, 2019). Research typically manifests strong evidence in that a large majority of no options or neutral responses reflect an unwillingness of respondents to provide a thoughtful answer (Hopper, 2016a). Therefore, the authors considered it an imperative for the survey questions to encourage thoughtful answers gleaned only after an extended period of time, and following a major shift in operations from onsite work to telework.

Once the data were collected for Phase 3, the multiple-choice answers were categorized and analyzed based on groupings of their Likert-scaled answers (McLeod, 2019). Next, coding was applied to the free-form text data. This methodology matched that of Phases 1–2 of the study, in which the researchers labeled and organized the data to identify the different themes and relationships based on keywords and phrases. Once the initial organization was completed, the similar themes and relationships were grouped and labeled in identifying different, common, and recurring themes in the response. The results of the analysis provided categorization of major themes described in this study.

> **While Phase 1 of this study targeted a single project and Phase 2 focused on a single division, the researchers felt that expanding the study to a larger number of projects within a department, including the associated support and leadership roles, would help confirm whether or not distributed operations in the form of maximum telework has been an effective means to support the Warfighters.**

The researchers acquired the Phase 3 data through survey questions given to the department workforce, and subsequently sent the survey to potential respondents via email, which explained the survey along with a web link to the following survey questions.

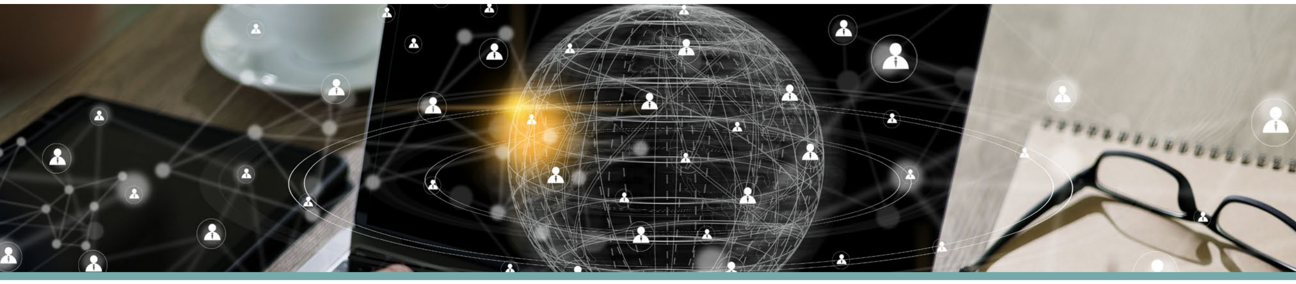
1. How would you classify your current position? (Technical, Management, Administrative, Support)
2. On average, how many days per week do you currently visit your onsite workplace? (Never; Occasionally, but not every week; 1–2 days per week; 3 days per week; 4–5 days per week)
3. Using the scale provided (1 = much less to 4 = much more), please answer the following two questions:
    a. How productive are you today under maximum telework compared to when most personnel were onsite daily prepandemic?
    b. How successful do you feel your project is today under maximum telework compared to when most personnel were onsite daily prepandemic?
4. What has been the most positive thing about maximum telework?
5. What could be done to make maximum telework more positive and/or productive (e.g., you as an individual and/or your team)?
6. What has surprised you (good/bad/indifferent) the most about maximum telework?

7. Once maximum telework ends, how many days per week should you be onsite for maximum effectiveness of your position?
8. Once maximum telework ends, how many days per week should most people be onsite for the maximum effectiveness of your project/team?

The questions were sent out as an anonymous survey to instill some level of trust and to protect the identities of the participants. In addition, the anonymous survey approach may have also helped encourage the workforce to provide accurate information in response to the survey without the sensitivity normally associated with some level of attribution. In addition, the survey questions solicited no specific, personally identifiable information that could be referenced back to a particular individual or project.

A number of limitations beyond the control of the researchers were identified but did not pose a significant issue during Phase 3 of the study. However, it warrants defining these limitations as they may affect the findings in future studies in the same area.

The first limitation was the number of participants during the department survey, which was sent to about 900 government employees. In the majority of scientific studies, the average survey response rate is about 33%, which would provide verifiable sample data for analysis (Lindemann, 2019). In this study, the researchers attained a 46% participation rate throughout the department workforce. While NIWC Pacific has a number of departments, a single department of about 900 people may be limiting but adequate in acquiring a good sample data set for a study. Especially since, out of 900 people, respondent totals were above the average survey response rates, which is more than adequate as sample data for a scientific study.



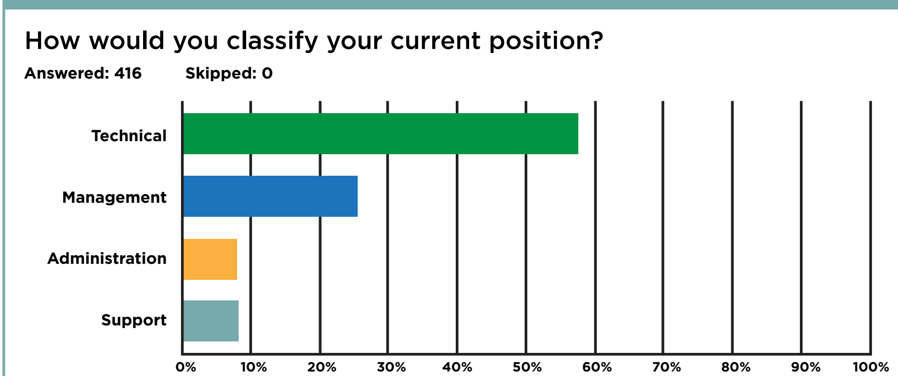
The second limitation was the scope of the participants. In this specific study, the survey was deployed only to one specific department rather than multiple departments. By studying a single department, the limitation may be that the department is not a general representative of the entire organization but rather only a subset. The third and final limitation was the personnel skills and distribution of positions of the department, which consisted of technical, management, administrative, and support staff. Other departments may perform a different mission, and therefore the personnel position diversity may vary among other departments.

Findings

Once the department workforce survey closed 10 days after its submission, the researchers collected and analyzed the results. The survey findings are summarized in this section.

a. In the Phase 3 study, the answers to Question 1 of the 8 questions listed in the previous section, regarding the technical role, significantly resemble the findings in Phases 1–2. However, the department survey provided a larger sample population, including technical, management, administrative, and support staff. As expected and based on the data acquired, the department survey provided an extended sample population on the roles. The roles were primarily technical for about 57% of the department respondents, with 25% of the respondents categorized as management, while support and administrative respondents each represented 8% (Figure 3).

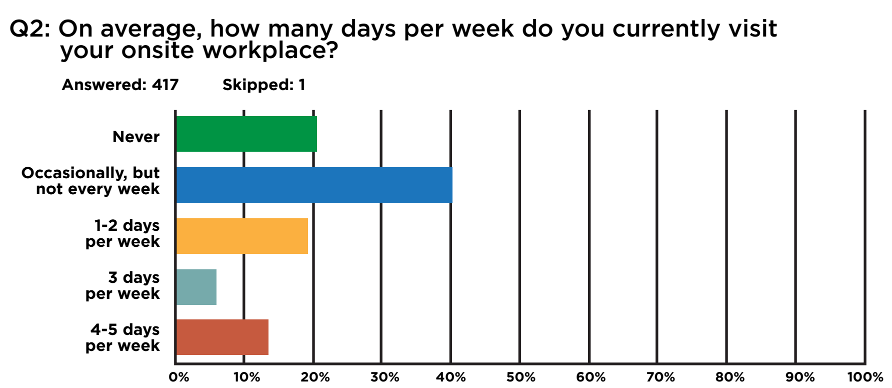
FIGURE 3. CLASSIFICATION OF POSITIONS



Answer Choices	Responses	
Technical	57.69%	240
Management	25.72%	107
Administration	8.17%	34
Support	8.41%	35
TOTAL		**416**

b. Question 2 addressed necessary onsite visits by personnel while distributed away from the office during maximum telework. As the organization started to recognize that onsite visits were necessary and could be performed safely, this provided insight about the number of onsite visits performed by personnel required to be in the office for the execution of their assigned duties. The survey reported that, at the time of the survey period, approximately 40% of personnel occasionally came onsite but not every week. It also showed that during this period about 21% never came onsite. While 19% of the respondents visited onsite 1 to 2 days per week, 6% visited 3 days per week, and 14% visited 4 to 5 days per week (Figure 4).

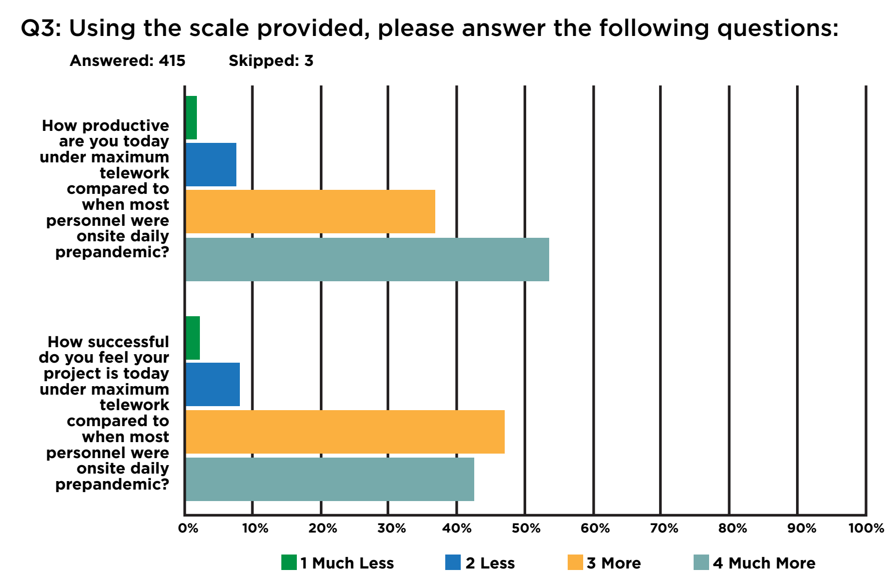
FIGURE 4. ONSITE VISITS TO THE WORKPLACE



Answer Choices	Responses	
Never	20.62%	86
Occasionally, but not every week	40.29%	168
1–2 days per week	19.42%	81
3 days per week	6.00%	25
4–5 days per week	13.67%	57
Published Results		**417**

c. Question 3 posed two subquestions that focused on productivity. The first question was based on how productive the respondent has been under maximum telework compared to when most personnel were onsite daily prepandemic. Fifty-four percent responded that they were *much more* productive during maximum telework, and 37% said that they were *more* productive. Eight percent responded that they were *less* productive while under maximum telework, and 2% said that they were *much less* productive. Question 2 was also related to productivity; however, the question focused on personnel perception of how successful projects were under maximum telework compared to when most personnel were onsite daily prepandemic. Forty-three percent responded that their projects were *much more* successful under maximum telework. Forty-seven percent responded that their projects were *more* successful, while 8% said *less* successful, followed by 2% who said that their project's success was *much less* under maximum telework compared to being onsite prepandemic (Figure 5).

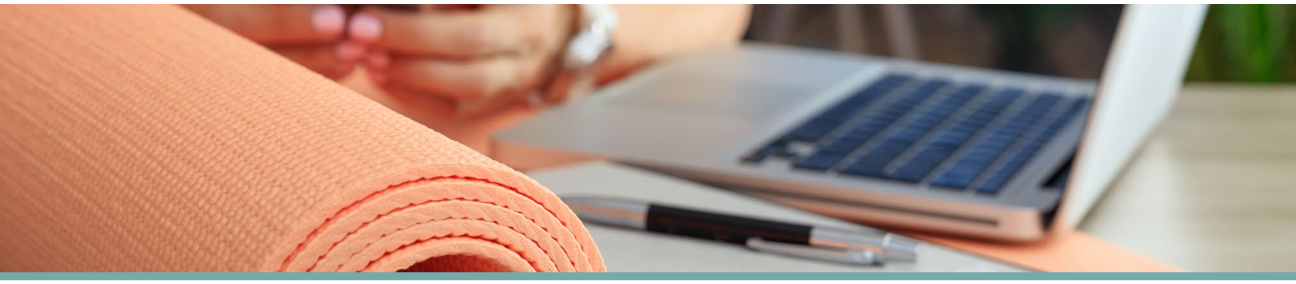
FIGURE 5. PERSONNEL PRODUCTIVITY AND PROJECT SUCCESS



	1 MUCH LESS	2 LESS	3 MORE	4 MUCH MORE	TOTAL	WEIGHTED AVERAGE
How productive are you today under maximum telework compared to when most personnel were onsite daily prepandemic?	1.69% 7	7.71% 32	36.87% 153	53.73% 223	415	4.33
How successful do you feel your project is today under maximum telework compared to when most personnel were onsite daily prepandemic?	2.19% 9	8.03% 33	47.20% 194	42.58% 175	411	4.20

d. In Question 4, the department workforce members were asked what they perceived as the most positive thing about maximum telework. Similar to the first and second survey, the workforce believed that maximum telework has created favorable benefits for them both at work and home. The following discussion is a summary of the results, synthesized from the respondents, based on both professional and personal benefits.

- Increased collaboration, productivity, and communication:
    - Increased organizational information technology remote capabilities and infrastructure to ensure success of individual tasks
    - Increased frequency of leadership updates and information distributed to the workforce
    - Decreased distractions and interruptions (e.g., water cooler chatter, unplanned office visits, etc.)
- Increased time efficiency:
    - Eliminated physical travel between home and work
    - Eliminated parking issues and unproductive travel time between onsite physical meetings
- Increased work-life balance:
    - Increased sleep, rest, and family time
    - Utilized time efficiently for mental and physical wellness (e.g., home gym, short walks, quiet breaks, etc.)
    - Increased flexibility with work-life balance in being able to schedule personal matters within a workday (e.g., doctor's appointment, cook a family meal, readily available for family needs, etc.)
    - Assisted in managing personal budget and time (e.g., minimizing fuel consumption, preparing/packing lunch, easily accessible and commutable telework locations allowing for proximity to personal and children's activities)



e. In Question 5, the department workforce was asked what the organization could do to make maximum telework more positive and/or productive (e.g., for you as an individual and/or your team). The results show variations of individual preferences. The following recommendations are a synthesized summary of the respondent results.

- Implement a well-defined and long-term telework program to enhance work-life balance while ensuring productivity is maintained:
    - Maintain maximum telework due to increased productivity and work-life balance
    - Align telework with each project and program need (e.g., number of days to telework, hybrid approach, maximum telework, etc.)
    - Implement a hybrid approach for working remotely and physically onsite (e.g., a 50-50 combination approach)
- Continue to improve information technology infrastructure to support offsite operations:
    - Better procedures and policies for employees
    - Better information technology support for employees
    - Better reliability of hardware and software tools for information technology productivity and collaboration (e.g., respondents expressed anxiety over whether collaboration tools will consistently work for them)
    - Better work collaboration tools installed on personal devices (e.g., integrate DoD collaboration tools into personal devices)
    - Better access to private networks and internal resources

- Better concept of operations for teleworking:
  - Identify and reserve timeframes for strategic thinking
  - Define teleworking policies and best practices (e.g., people are in email, meetings, and chat all day without any breaks)
  - Implement training to perform work duties efficiently and effectively during maximum telework

f. In Question 6, the department workforce was asked what surprised them the most about maximum telework. The majority of the workforce responded that maximum telework increased their efficiency and productivity while working from home. In addition, they reported that maximum telework streamlined communication and collaboration across the whole organization. The respondents also expressed that work-life balance increased, with less stress due to less commuting and no office distractions. A small group missed the interaction with other people during the workday and opportunities to break up the monotony of being in front of the computer all day.

- Increased efficiency working from home:
  - Organization assisted the respondents in their transition towards maximum telework by instilling trust among the workers to be able to perform their functions without in-person supervision
- Increased productivity:
  - Coworkers were able to collaborate, using tools to get work done
  - Transition from meetings to tasks was easy due to virtual versus physical interactions

The majority of the workforce responded that maximum telework increased their efficiency and productivity while working from home.

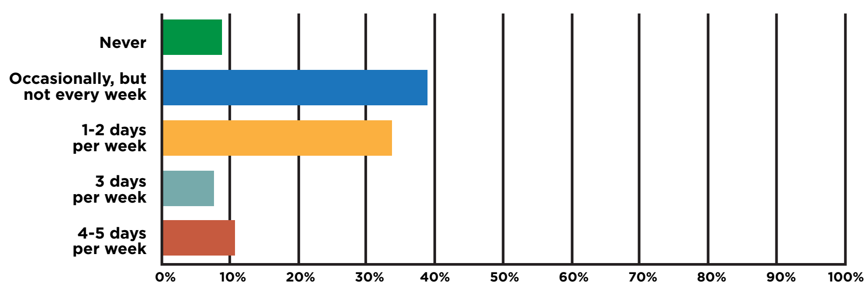
- Improved work-collaboration technology and communication:
  - Work-provided tools have helped increase productivity and delivery of capability to the users
- Increased work-life balance:
  - More time with family and friends after work
  - Ability to focus on getting tasks completed without distractions within the workday
- Decreased stress and increased quality of life:
  - No commute, no parking issues, and no distractions
  - More time to integrate physical health into the telework schedule
  - More energy at the end of the workday
- Decreased work socialization and interaction:
  - Becoming disconnected from colleagues
  - Missing social interactions with colleagues after work
- Increased workdays' perceived length:
  - Workdays seemed longer, with associated increased monotony due to being in front of a computer all day

g. In Question 7, the department workforce was asked how many days per week they should be onsite for maximum effectiveness of their position once maximum telework ends. The majority of the respondents favored a hybrid approach in which 39% would like to occasionally be onsite but not every week, followed by 34% who felt they should be onsite 1–2 days per week. Eleven percent envisioned being onsite 4–5 days per week, while another 8% thought that their position required their physical presence onsite at least 3 days per week. The remaining 9% responded that their position should never be back onsite (Figure 6).

FIGURE 6. ONSITE PER POSITION

Q7: Once maximum telework ends, how many days per week should you be onsite for maximum effectiveness of your position?

Answered: 416 Skipped: 2



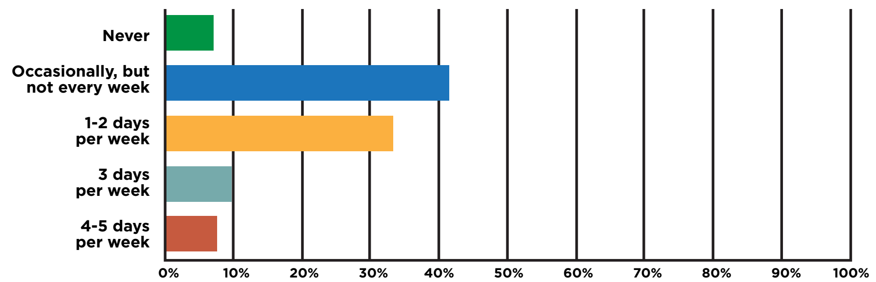
Answer Choices	Responses	
Never	8.89%	37
Occasionally, but not every week	38.94%	162
1–2 days per week	33.89%	141
3 days per week	7.69%	32
4–5 days per week	10.56%	44
TOTAL		**416**

h. In Question 8 of the department survey, the department workforce was asked how many days per week most people should be onsite for maximum effectiveness of their project/team once maximum telework ends. The majority of the respondents favored a hybrid approach in which 42% would like their project/team onsite occasionally, but not every week. Thirty-three percent responded that their project should be onsite 1–2 days per week. Ten percent would like their project/team to be onsite 3 days per week, while another 7% thought that their project/team should be onsite 4–5 days per week. The remaining 7% responded that their project/team should never be back onsite (Figure 7).

FIGURE 7. ONSITE PER PROJECT-TEAM

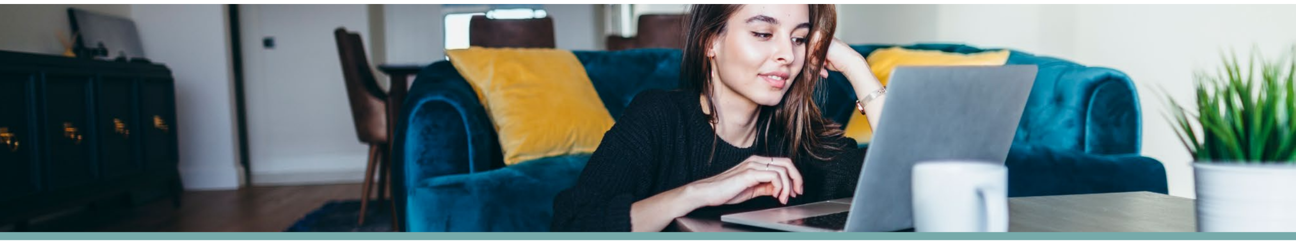
Q8: Once maximum telework ends, how many days per week should most people be onsite for maximum effectiveness of your project/team?

Answered: 416 Skipped: 2



Answer Choices	Responses	
Never	6.97%	29
Occasionally, but not every week	41.59%	173
1–2 days per week	33.41%	139
3 days per week	10.34%	43
4–5 days per week	7.69%	32
TOTAL		**416**

As previously stated, the Defense Acquisition community has been concerned with ensuring the DoD workforce is able to satisfy the cost, schedule, and performance of national security and defense projects and programs. This study revealed data that the workforce perceived they were able to persevere working through a telework environment for over 2 years while continuing their long-term success in supporting projects and delivering capabilities to the nation's Warfighters. This study provided additional data and insight not available through the previous two surveys. Most importantly, at least from the authors' perspective, this study helped answer questions related to workforce productivity and project success over



time. It also provided leadership some answers regarding workplace onsite visits, individual and project success, positive and productive perceptions on maximum telework, and insights to how the workforce perceives the return to the workplace from both an individual and project perspective.

Suggestions for Future Research

This study can be replicated with the same survey methodology and a variety of subjects and participants. The survey allows for the flexibility and quick deployment to other organizations interested in exploring operational impacts amidst rapid organizational transformation in a new operating environment, especially in relation to workforce productivity and project success. It can also be applied to other situations in an attempt to determine whether roles, age groups, or cultures influence factors associated with perceived workforce productivity and/or project success during distributed operations.

Based on this study, the authors identified a number of future research topics that may help build on this body of knowledge, including:

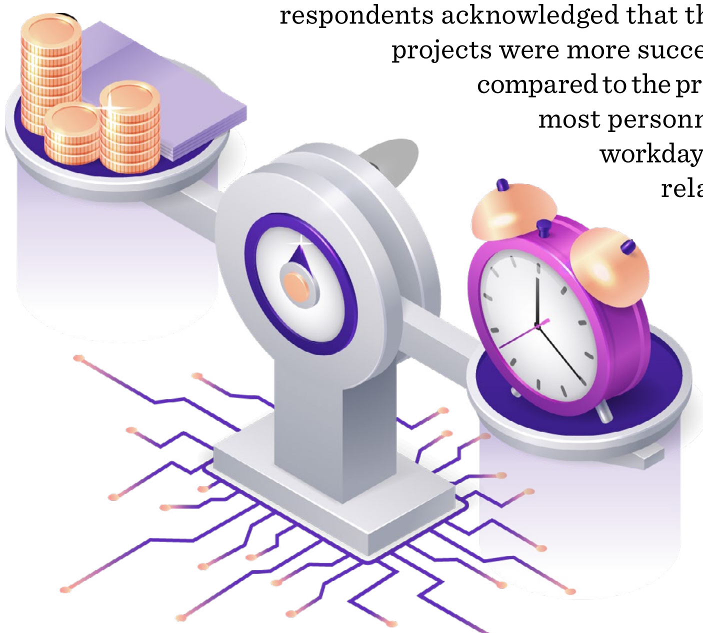
- Management perception of guiding the workforce through telework
- Identifying and addressing the constraints and limitations of telework
- Impact of supporting a classified project or program with the workforce performing some level of telework
- Age and gender factors in the workforce and performance in a telework environment
- Assessing impacts and perceptions by positions in a government telework environment (i.e., management vs. technician versus administrative personnel, etc.)

> **Ultimately, the sampled workforce is interested in seeing some level of telework factored into the new definition of a normal operating environment.**

- Measuring productivity of teleworkers by organization management in relation to performance assessments
- Measuring telework cost versus cost savings to the government
- Impacts of supporting operations and maintenance of government customers in a telework environment
- Assessing overall effects of returning to work from a cost-and-performance standpoint for the government and individuals
- Comparison of telework productivity perceptions based on organizational roles (management, technical, administrative, and support staff)

Conclusions

The survey sent to the department workforce provided insightful data in understanding the effects that operating in a distributed, maximum telework environment had on the personnel supporting a Navy laboratory organization. It provided key information on the effects teleworking had on workforce productivity, project success, and work-life balance. Within the past 2 years (early 2020 to present), the vast majority of the respondents acknowledged that they were more productive and their projects were more successful during maximum telework as compared to the previous operating environment where most personnel were in the physical office every workday. Also, a great deal of insight emerged related to distributed operations such as increased communication and collaboration by the team and improved work-life balance. It was also revealing that people reported they were less productive under the previous,



nonteleworking environment due to dealing with the logistics of commuting, parking, and office distractions. Ultimately, the sampled workforce is interested in seeing some level of telework factored into the new definition of a normal operating environment. They also expressed that further investment in collaborative information technology infrastructure will aid in their effectiveness and overall project success (Tolentino et al., 2021). Without a study such as this, NIWC Pacific leadership could have viewed the distributed telework environment as disadvantageous in its ability to support the Warfighters. However, based on this survey's findings, the NIWC Pacific C2E2 Department now views teleworking as a normal part of the workforce operations that should be welcomed and embraced.

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Author Biographies

DR. GLENN TOLENTINO

has been an engineer, researcher, and innovator in the Command and Control (C2) and Enterprise Engineering competency throughout his career. He has been a major contributor in the design, development, and deployment of nationally recognized defense and intelligence systems. He received his BS in applied mathematics from San Diego State University, and his MS in software engineering and PhD in computer science from Southern Methodist University.

(E-mail address: glenn.s.tolentino.civ@us.navy.mil)

DR. JOHN WOOD

has spent his career pursuing perfection in areas where less-than-perfect performance can be deadly. In more than two decades of military service, civilian sector innovation, and academia, he has applied his systems engineering expertise to advance high-profile programs in healthcare, aviation, and defense. Dr. Wood received his BS in electrical engineering from the U.S. Naval Academy and his PhD in systems engineering from the George Washington University.

(E-mail address: john.n.wood.civ@us.navy.mil)

DR. SHANE RILEY

has a doctorate in business administration with a specialization in public administration, as well as a BA and MA in international relations and political science. Dr. Riley has extensive professional experience working in the private and public sectors, both domestic and international. Dr. Riley specializes in strategic management, data science, enterprise resource planning, business intelligence, political science, and international affairs.

(E-mail address: shane.c.riley.civ@us.navy.mil)

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Proactive Obsolescence

MANAGEMENT METHODS FOR C5ISR SYSTEMS: Insights from PRACTITIONERS

Image designed by Nicole Brate

Matthew D. Chellin and Erika E. Miller

Obsolescence is a significant challenge for the Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) community. Obsolescence can negatively affect a C5ISR system's cost, schedule, performance, and readiness. This article examines the challenge of obsolescence for C5ISR systems by focusing on the U.S. Army at Aberdeen Proving Ground, Maryland, and their industry partners. Data were gathered by conducting interviews with 20 individuals who had experience with C5ISR systems: 10 government Army civilians and 10 industry partner employees. The objective of this study is to synthesize insights from the experiences of government and industry practitioners that mitigate diminishing manufacturing sources and material shortages (DMSMS) challenges.

The obsolescence mitigation areas described in this article include proactive and reactive obsolescence mitigation, obsolescence mitigation methods, opportunities for alternative components and planned improvements, the importance of DMSMS contracting language, and obsolescence management practices to avoid. This article also offers approaches grounded in practitioner experiences to mitigate obsolescence through a preliminary proactive obsolescence management model, risk mitigation framework, and metrics. The combination of the obsolescence mitigation approaches discussed in this article has the potential to achieve greater system readiness, more availability, better maintainability, and lower costs for C5ISR systems.

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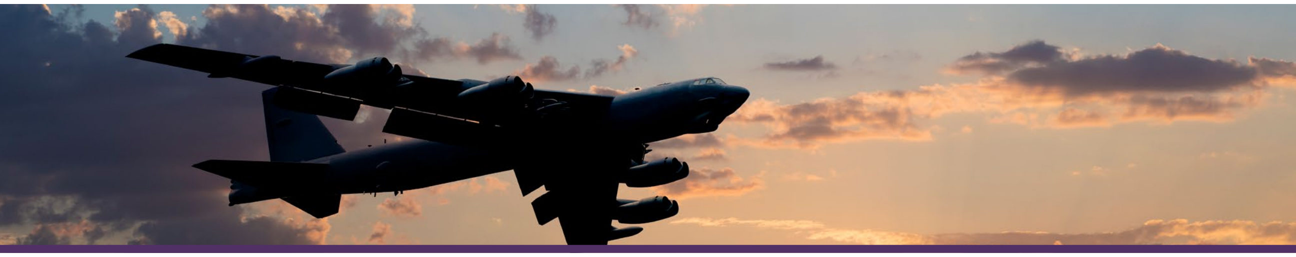
Obsolescence is a major challenge that affects all Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) systems. A proactive obsolescence management approach focusing on the planning and execution of activities to support early obsolescence mitigation solutions is critical for the long-term affordability and availability of C5ISR systems. Many benefits are associated with achieving successful proactive obsolescence management, such as greater system readiness, more availability, better maintainability, reduced schedules, and lower costs.

Background

A well-known example in military aviation of a system that has experienced multiple obsolescence challenges in its history is the B-52 bomber (Newman, 2016).

> The B-52 bomber was originally awarded in 1946 and is projected to be in service into the 2040s. While this instance may represent an extreme case for program lives, it is not uncommon for larger DoD programs to extend for several decades. As these systems age, the electronic and software systems within them will become obsolete over time and will eventually become unreliable, unmaintainable, unserviceable, underperforming, or nonfunctional, leaving the Warfighter at risk of losing superiority on the battlefield. (para. 5)

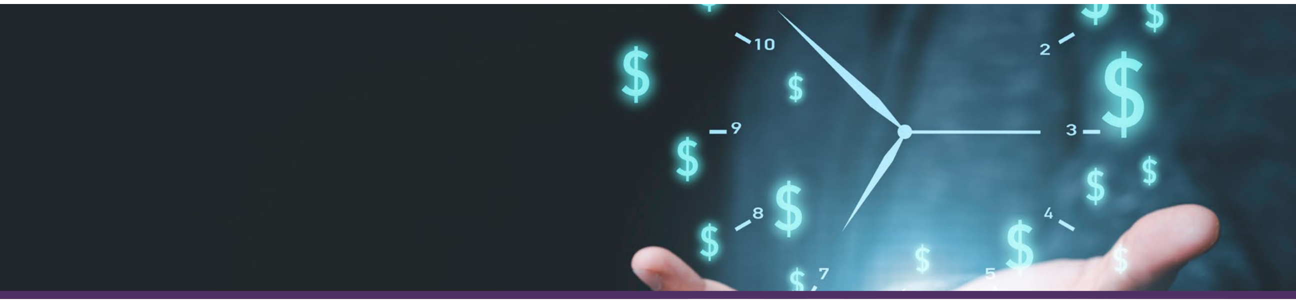


The B-52 bomber is a very long-lived system example, which has some legacy communication systems on board; this magnifies the importance of managing obsolescence to save cost, schedule, and operational availability. In the case of long-lived systems, getting ahead of obsolescence challenges is critical because the outcomes will be realized many times over.

An example follows of how obsolescence challenges negatively impact systems. Imagine learning one day that the component needed to support a system is no longer available. This discrepancy is detected only after trying to place an order, and it comes as a complete surprise that a needed component is no longer available due to obsolescence. This leads to a scramble to find a replacement, to qualify an alternate component, or to find another source of supply. As a part of the process to qualify the replacement component, engineering changes are made to this component and/or the receiving system. This results in a newly designed or redesigned component, and all the processes are accelerated to provide the replacement component as quickly as possible. This acceleration is important because it avoids the alternative of reducing the number of available systems. Reflection on this series of events results in the realization that failure to proactively manage obsolescence has resulted in delayed schedules, increased costs, and lower supportability. The research in this article will assist acquisition practitioners with mitigating obsolescence challenges before their unforeseen immersion in what becomes a reactionary situation.

This article examines the perspectives of government and industry practitioners who are routinely confronted with obsolescence challenges, with the focus on C5ISR systems managed by the U.S. Army at Aberdeen Proving Ground, Maryland. This research is applicable to C5ISR systems hardware and its embedded software. The government and industry participants were interviewed about their extensive experiences, including successful obsolescence mitigation approaches, unsuccessful obsolescence mitigation approaches, and ways to improve obsolescence mitigation for C5ISR systems. This article synthesizes and builds upon these insights to offer a preliminary framework, model, and metrics to the community of acquisition practitioners and researchers to combat the obsolescence challenge. The insights of the practitioners that participated in this research significantly contributed to our collective knowledge of potential methods to achieve proactive obsolescence mitigation for C5ISR systems.

The inability to obtain replacement components for a system is commonly addressed within the context of diminishing manufacturing sources and material shortages (DMSMS). Significant advantages are associated with mitigating DMSMS challenges that can be leveraged by putting into practice proactive initiatives in lieu of reacting to unforeseen issues requiring immediate attention.



Literature Review

A review of the literature supports the importance of proactive obsolescence management for DMSMS. To fill gaps in knowledge and identify preliminary approaches for proactive obsolescence management, the literature was integrated with responses from the participants in this study. Many examples highlight the importance of proactive obsolescence management to assist acquisition practitioners with obsolescence mitigation. For example, Department of Defense Instruction (DoDI) 4245.15 Diminishing Manufacturing Sources and Material Shortages provides instruction on managing and mitigating challenges associated with DMSMS (Department of Defense [DoD], 2020). A more detailed guideline is *SD-22 Diminishing Manufacturing Sources and Material Shortages: A Guidebook of Best Practices for Implementing a Robust DMSMS Management Program*, which gives specifics for many obsolescence management methods such as the DMSMS Management Teams, DMSMS Management Plans, DMSMS monitoring and surveillance, and many other DMSMS management considerations (DoD, 2022). More information to assist with contracting can be found in *SD-26 DMSMS Contract Language Guide Book* (DoD, 2019). Sandborn (2004) highlights the sustainment advantages and cost benefits associated with adopting a proactive approach in lieu of a reactive approach to obsolescence management. Similar support for a proactive approach is found in Sandborn and Terpenny (2006). The importance of proactive obsolescence management is further supported with modeling in the Strategic Proactive Obsolescence Management Model (Meng et al., 2014). Another modeling approach to support proactive obsolescence management is provided for the interaction between components using a Weibull's distribution in the *FMECA-Based Risk Assessment Approach for Proactive Obsolescence Management* (Trabelsi et al., 2020). In addition, Sandborn (2007) notes the importance of proactive obsolescence management to mitigate software obsolescence; however, Sandborn suggests that more is needed to assist with the mitigations.

Research has also been conducted in the area of power plants. Clancey (2018) highlights the importance of planning in advance to mitigate obsolescence for a nuclear power plant. Many best practices support proactive obsolescence management; the modeling described in Meyer et al. (2004) includes many such practices that drive both proactive and reactive obsolescence management. Lastly, the use of risk to mitigate several obsolescence challenges is discussed by Rojo et al. (2012).

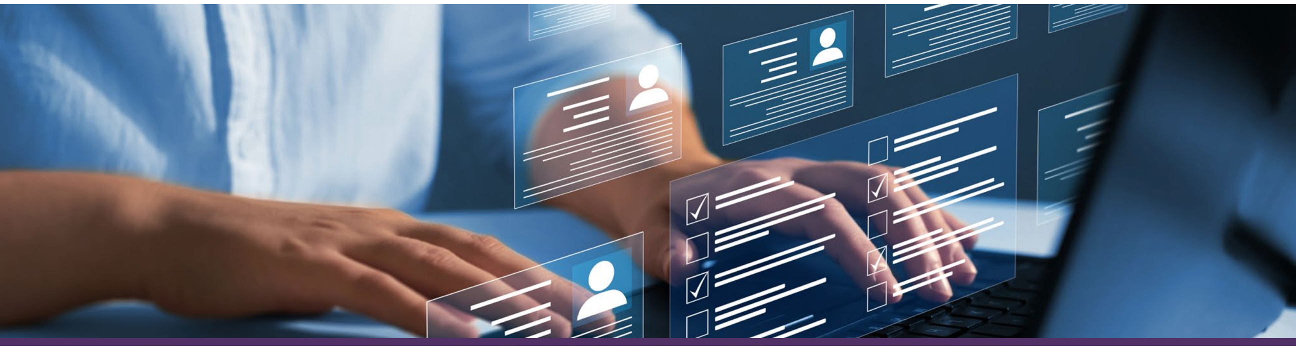
The U.S. Army and its industry partners are challenged by obsolescence in support of C5ISR systems. Often solutions are reactive to the challenge posed by obsolete components. This results in lower operational availability, longer production and repair schedules, and greater system costs.

This article is intended as complementary to research in the area of obsolescence management. It presents a newly developed preliminary framework, model, and metrics, which have the potential to contribute significantly to mitigation of the challenges that DMSMS poses to C5ISR systems. The literature clearly shows that the merits and theory behind proactive obsolescence management are well understood. However, obsolescence is an area that continues to be a major challenge for acquisition practitioners, who are responsible for the long-term support of C5ISR systems. Therefore, this subject deserves further research to expand the existing methods and new methods to mitigate obsolescence challenges.

Problem Statement

The U.S. Army and its industry partners are challenged by obsolescence in support of C5ISR systems. Often solutions are reactive to the challenge posed by obsolete components. This results in lower operational availability, longer production and repair schedules, and greater system costs. More robust, proactive, DMSMS mitigation methods are needed to manage the numerous obsolescence challenges. Proactive DMSMS mitigation methods support higher system readiness, greater supply availability, and lower life-cycle costs. This article sets forth three primary research questions:

1. How does the Army proactively mitigate obsolescence of C5ISR systems?
2. How does the defense industry mitigate obsolescence for the Army's C5ISR systems?
3. Are there differences between how the Army and defense industry control obsolescence mitigation management for the Army's C5ISR systems?



Methodology

The research design for this study is qualitative and uses the phenomenological research methodology, which consists of interviewing participants about their experiences with mitigating obsolescence challenges for varied defense weapon systems. The participants included both government employees from the U.S. Army located at Aberdeen Proving Ground, Maryland, and their industry partners. All participants have experience supporting C5ISR systems in the operations and support phase of the system life cycle. The participants included 10 government Army civilian employees 10 industry partner employees (total of 20 government and industry participants), nine engineers, six project managers, four logisticians, and one business manager. The 10 government Army civilian employees have an average of 23 years of experience. Similarly, the 10 industry partner employees have an average of 23.2 years of experience. The participants were all asked 13 open-ended questions in individual interviews (Table 1). The interviews lasted approximately 30 to 60 minutes. This study had Institutional Review Board approval from Colorado State University.

TABLE 1. INTERVIEW QUESTIONS FOR ALL 20 PARTICIPANTS

Interview Questions
Are you with the government (Army) or industry?
What is your area of expertise?
How many years of experience do you have?
What training have you received to mitigate obsolescence?
What tools do you use to mitigate obsolescence?
How do you identify obsolescence for your system(s)?
What role does risk management play in identifying obsolescence?
What role does risk management play in mitigating obsolescence?
How has contract language assisted or hindered your ability to mitigate obsolescence?
When do you normally discover an obsolescence problem for your system(s)?
What has worked well to mitigate obsolescence?
What has not worked well to mitigate obsolescence?
What are your organization's future initiatives to mitigate obsolescence beyond the current process/practice (next level)?

Analysis and Results

Participant responses were synthesized to identify current methods for proactive obsolescence mitigation, training for proactive obsolescence mitigation, opportunities for alternative components and planned improvements, the importance of DMSMS contracting language, and obsolescence management approaches to avoid. Overall themes from participant responses and the literature were then used to develop a preliminary proactive obsolescence management model, a preliminary proactive obsolescence risk mitigation framework, and preliminary metrics. The knowledge gained from this research is intended to strengthen the knowledge base and available methods for practicing proactive obsolescence mitigation best practices in support of C5ISR systems.

Understanding Proactive Versus Reactive Obsolescence Mitigation

The participants in this study shared their obsolescence mitigation experiences; many had experiences using both proactive and reactive obsolescence mitigation methods. The preference was always to be proactive; however, some survey respondents reported that they had often been surprised by material shortages, which only left them the reactive obsolescence mitigation approach option. The mitigations focused on C5ISR system components, with the obvious exception of very low-risk parts (e.g., bolts, nuts, and screws). In some cases, identifying which mitigation approaches are proactive or reactive can be difficult. For example, Life-of-Type Buys solve an immediate challenge and may appear proactive for the long-term of the procured component. However, such buys are reactive because they act as an approximate buffer and do not account for the lack of long-term design stability of the components within the system. On one hand, some of the Life-of-Type Buy components likely will not be used. On the other hand, one could err through buying too few components, further worsening the obsolescence challenge. Conversely, proactively redesigning an alternate component as well as several of the surrounding components 5 years before the need for a Life-of-Type Buy will mitigate the negative schedule, cost, and availability challenges of the DMSMS risk. Table 2 includes examples to assist in understanding proactive obsolescence mitigation approaches versus reactive obsolescence mitigation approaches.

TABLE 2. EXAMPLES OF PROACTIVE VS. REACTIVE OBSOLESCENCE MITIGATION APPROACHES

Proactive Obsolescence Mitigation Approaches	Reactive Obsolescence Mitigation Approaches
Analyze the system's bill of materials with a predictive analysis tool to plan the appropriate development or selection of replacement components	Life-of-Type Buys – Order all the end-of-life components forecasted for the life cycle of the system (Trabelsi et al., 2020)
Establish and maintain a DMSMS Management Team	Harvest components/parts from defielded systems
Establish and update a DMSMS Management Plan	Near-term redesign
Flow DMSMS contracting language through the supply chain to monitor the health of components and obtain recommended solutions	Near-term design modifications
Use Open System Architecture design solutions	Request manufacturer to continue producing the component(s)/part(s)
Early qualification of alternate manufacturing sources for a replacement that meets form, fit, and function criteria	Find an immediate substitute replacement that meets form, fit, and function criteria
Design by partitioning the system for logical component-level and cost-effective future design changes	Increase maintenance to extend the useable life of the system
Early development and use of metrics	Use the system less and lower the standard operating performance criteria to extend the useable life of the system; e.g. lower power usage reduces heat

> **The preference was always to be proactive; however, some survey respondents reported that they had often been surprised by material shortages, which only left them the reactive obsolescence mitigation approach option.**

Methods for Proactive Obsolescence Mitigation

The research participants' methods of proactively mitigating the obsolescence of C5ISR systems for the Army at Aberdeen Proving Ground compared to methods of the defense industries that provide support for these systems are very similar. Both recognize the advantages of proactive obsolescence mitigation and the disadvantages of reactive obsolescence mitigation, such as the schedule and cost impacts. Among the interviews, several methods stood out that support proactive obsolescence mitigation. These methods include the following:

- Establish and maintain a DMSMS Management Team.
- Establish and update a DMSMS Management Plan.
- Analyze the system's bill of materials (BOM) with predictive analysis tools.
- Flow DMSMS contracting language through the supply chain for monthly feedback on the health of components and recommended solutions.

DMSMS Management Team

As stated in *SD-22 Diminishing Manufacturing Sources and Material Shortages: A Guidebook of Best Practices for Implementing a Robust DMSMS Management Program*, "all program offices should have a DMSMS management team (although it may be small under certain circumstances) that oversees the execution of a DMSMS management plan" (DoD, 2022, p. 24). Further, several research participants highlighted that, in practice, establishing the DMSMS Management Team is the critical first step. This is the team that will do the majority of the activities required to achieve proactive obsolescence management for a system.

DMSMS Management Plan

These research participants emphasized that the essential early assignment of the DMSMS Management Team is to create and receive approval of the DMSMS Management Plan. This plan includes the strategy and execution activities to achieve proactive obsolescence management for a system. Moreover, the DoDI 4245.15 states, "develop … and maintain a DMSMS management plan to document proactive, risk-based DMSMS management processes and team structures" (DoD, 2020, p. 8).

The research participants' methods of proactively mitigating the obsolescence of C5ISR systems for the Army at Aberdeen Proving Ground compared to methods of the defense industries that provide support for these systems are very similar.

Bill of Materials

Analyzing the system's BOM with a predictive analysis tool emerged as a high-value proactive obsolescence mitigation activity among the research participants. This is an important method to support proactive obsolescence management. Using a predictive analysis tool to analyze the BOM is a foundation of proactive obsolescence management and will continually inform the DMSMS Management Team and the DMSMS Management Plan, as well as assist with monitoring the supply chain for DMSMS risks and issues. Additionally, this information supports the tailoring of the DMSMS contracting language. Examples of predictive analysis tools include Multifunctional Obsolescence Resolution Environment (MORE), Advanced Component Obsolescence Management (AVCOM), Electronic Resellers Association International (ERAI), and Information Handling Services (IHS) Haystack. These examples are intended to inform the defense acquisition community of some potential options as identified by the research participants, and their inclusion here is not an endorsement of any one tool in lieu of another. Further, the participants highlighted risk management as an essential aspect of proactive obsolescence mitigation. Unique components often change due to frequent technology advances and have one or few suppliers, are high risk, and require focused expertise. Less intensive proactive effort is still required to mitigate DMSMS risk for components that have a predictable useful life with planned replacements. The components with the least DMSMS risk are those that rarely change, such as the system's frame and assembly hardware (nuts, bolts, etc.).

DMSMS Contracting Language

The research participants focused on the importance of flowing the DMSMS contracting language through the supply chain for feedback on the health of components, and recommended solutions were identified as very important for achieving proactive obsolescence management for a system. Some participants included their experiences with flowing down DMSMS contracting language to a subcontractor or vendor. However, the participants identified no process to verify that the DMSMS language flowed through the supply chain to include all subcontractors, vendors, and material providers. We recommend verifying the completion of the contract language flow down through the supply chain using the metric "DMSMS Contract Language Supply Chain Flow Down Verification," which is presented later in this article.

Training for Proactive Obsolescence Mitigation

Many participants identified the importance of training to support an acquisition practitioner's efforts. In some cases where a participant had not received formal training, the survey reflected a comment indicating how helpful it would have been to receive prior training, especially when first addressing obsolescence challenges for DoD weapon system(s). As a result, we gathered a list of training available from some of the participants in this study (Table 3). This is not a recommendation or endorsement of the listed training classes. Their mention in this article is to provide and promote awareness within the defense acquisition community.

TABLE 3. PARTICIPANT-IDENTIFIED OBSOLESCENCE MITIGATION TRAINING

Training Source	Class/Seminar Number	Class/Seminar Name
Defense Acquisition University	LOG 0630	Parts Management Executive Overview
	LOG 0640	Diminishing Manufacturing Sources and Material Shortages
	LOG 0650	Diminishing Manufacturing Sources and Material Shortages Fundamentals
	LOG 0660	Diminishing Manufacturing Sources and Material Shortages Executive Overview
	LOG 0670	Diminishing Manufacturing Sources and Material Shortages Basic Component
International Institute of Obsolescence Management (IIOM)	-	IIOM Certification 3-Day Course
	-	IIOM Online Conference Seminars

Opportunities for Alternative Components and Planned Improvements

Several participants shared their experiences with harvesting components from decommissioned systems to address immediate shortages due to obsolescence. This is a highly reactive mitigation action to address obsolescence; however, an opportunity for much learning can emerge from this type of challenge. One lesson is to design or redesign these components several years ahead of a system repair. The alternate component should be designed for greater reliability, particularly if the component has a reliability challenge. Further, test data can be used to identify the medium- to high-risk components to select for an early alternate component design and improvements. On one hand, the redesign of an obsolete component is an opportunity to add or refresh capability and supportability. On the other hand, planning the phasing out of a component, based on forecasting its end of life, assists with promoting better replacement component planning. Further, the advance planning of schedules to integrate a replacement end-of-life component or an increased capability component is an opportunity to save resources (e.g., lower DMSMS case resolution costs, lower modification costs, and shorter schedules).

One proactive obsolescence mitigation approach is to identify lower reliability components 5 years in advance of forecasted obsolescence, then select or design form-fit-function alternate components to improve the availability, reliability, and cost for the components that present higher risk. Reliability is one example; in some cases, changing the technology is necessary, as when the industry changes to producing the component only with a more durable material. Therefore, designing this improved alternate component as a form-fit-function replacement should begin with the identification of the new material. The key takeaway is to plan the redesigning of components to be available 5 years in advance of the forecasted current components' end of life; this will lower risk, increase availability, and lower long-term supportability costs.

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Importance of DMSMS Contracting Language

Both the Army and industry research participants stressed the importance of including language in the contract that addresses obsolescence/DMSMS monitoring, reporting, and mitigation. This language includes areas such as a forecast for when components and parts will become obsolete and prompts the industry partner to recommend one or several solutions for the Army's consideration. The inclusion of this language is an enabler for the Army to proactively mitigate obsolescence for C5ISR systems, as well as a mechanism for industry to proactively plan for mitigating obsolescence of the system. The absence of this type of contracting language communicates a lack of importance to industry and results in minimal to no proactive effort to mitigate obsolescence. This finding reinforces the importance of DMSMS contracting language because industry performs to the funded requirements in the contract. Lastly, no participants identified using obsolescence metrics to assist with guiding and evaluating an organization's methods for proactively mitigating obsolescence. Therefore, a gap in our research exists, but an opportunity emerges for acquisition leaders to recognize their importance and implement metrics within these organizations, on the contract, and through the supply chain. Such early identification of obsolescence challenges and mitigation recommendations could achieve greater proactive obsolescence management for C5ISR systems.

Obsolescence Management Approaches to Avoid

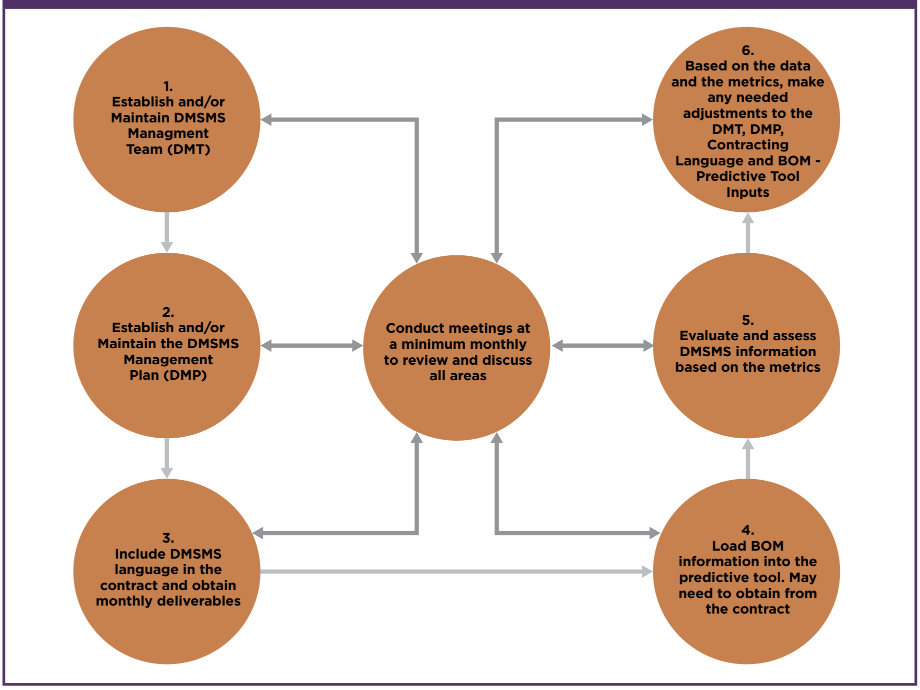
The obsolescence management approaches to avoid include ignoring the obsolescence problem, using reactive instead of proactive obsolescence management, and addressing obsolescence challenges as a one-time issue. Many participants explained the importance of actively managing obsolescence challenges and pointed out the significant drawbacks to ignoring obsolescence. Ignoring the obsolescence problem worsens the negative impacts to a system's readiness, availability, maintainability, and costs. Further, these aforementioned negative impacts are also experienced when the obsolescence management is reactive. Lastly, addressing obsolescence challenges as a recurrent issue and investing in the DMSMS Management Team, DMSMS Management Plan, and a predictive tool that leverages collective obsolescence mitigation knowledge are essential for basic proactive obsolescence management. The predictive tool could be provided by a third party or internally developed within the organization. Using a tool supports a structured proactive approach to solving obsolescence challenges, and it benefits from the synergy of the collective knowledge of many practitioners.

Preliminary Proactive Obsolescence Management Model

Based on government and industry insights for Army C5ISR systems, we developed a preliminary model (Figure 1) to assist defense acquisition organizations and defense industries with implementing and maintaining proactive obsolescence management practices. The model first focuses on the DMSMS Management Team, which is essential because this team does the majority of the planning, coordination, and execution. The DMSMS Management Team then creates the DMSMS Management Plan, which includes all the key areas needed to proactively manage obsolescence. Next is the obsolescence management contracting language, which includes the key areas to report the DMSMS status for all the components. Additionally, this is the place to include the language that allows industry to produce mitigation plan(s) for all the high- and medium-risk components proactively. Subsequent selection and application of a predictive tool on the BOM information may help locate current and projected DMSMS challenges. This information will come from the contractor's reports and/or an inspection of the system's components by the engineering and/or logistics employees. The next step is to evaluate the DMSMS data with the metrics to gain an understanding of the components that require short-term mitigation (less than 5 years) and the components that require long-term mitigation (more than 5 years and less than 12 years). Acquisition practitioners are advised not to invest effort in components and materials that rarely change (i.e.,

very long-term—more than 12 years). The metrics may also assist with improvements in processes, trade-off analysis, training, etc. Lastly, decide which areas need to change. For example, add team members with different areas of expertise to the DMSMS Management Team, update the DMSMS Management Plan, change the BOM to a redesigned component or a selected alternate component, or change contract language. Repeat the process, then review DMSMS information with the team on a monthly basis at a minimum to maintain a proactive obsolescence management approach.

FIGURE 1. PRELIMINARY PROACTIVE OBSOLESCENCE MANAGEMENT MODEL



Obsolescence Risk Analysis and Modeling

The participants recognized the importance of identifying and mitigating the risk of projected component obsolescence to assist with achieving proactive obsolescence management for C5ISR systems. Typically, acquisition practitioners must evaluate many considerations regarding obsolescence management, such as frequency of design changes, reliability, ageing systems, cost, and component availability within the supply chain.

Based on the insights and concerns of the participants, we constructed a preliminary framework for obsolescence risk mitigation (Table 4), which categorizes the inputs and outputs to assist with mitigating obsolescence in C5ISR systems. We offer this framework to the acquisition community to assist with proactively managing such risk. This framework provides criteria to perform analysis of a system's DMSMS risk. Reactive obsolescence management is associated with the components that are assessed as medium- to high-risk. Proactive obsolescence management is associated with the components that are assessed as low-risk.

TABLE 4. PRELIMINARY PROACTIVE OBSOLESCENCE RISK MITIGATION FRAMEWORK

Inputs	Outputs		
Indicators Number of Manufactures	*Low Risk* 3 or more manufactures	*Medium Risk* 2 or more manufactures	*High Risk* 1 manufacturer
Cost of Component and/or Part	Cost growth is not more than 10% for the component/part	Cost growth is more than 10% but less than 25% for the component/part	Cost growth is more than 25% for the component/part
Schedule of Component/ Part	Estimated delivery schedule is 6 months or less	Estimated delivery schedule is 6–12 months	Estimated delivery schedule is more than 12 months
Frequency of Design Changes	Estimated design changes are 12 years or greater	Estimated design changes are more than 5 years but less than 12 years	Estimated design changes are less than 5 years
Next Generation, Upgrade and Update Planning - Roadmaps for technology, systems, or products	Roadmaps indicate firm dates of the replacement component/part; e.g., month and year or quarter and year	Roadmaps indicate a date range; e.g., a span of several years for the replacement component/part	No roadmap or roadmaps do not indicate any dates
Component Replacement Planning	Planning component replacement early in the service life based on forecasted operational hours and cycles: One cycle is from powering a component on to powering the component off	Planning component replacement in the middle of the service life based on forecasted operational hours and cycles	No to minimal planning of component replacement

Preliminary Proactive Obsolescence Mitigation Metrics

The importance of implementing metrics was also recognized by several of the research participants from the Army and their industry counterparts. However, a gap exists regarding what those metrics should be. Some organizations highlighted the importance of managing DMSMS with a system of cases to document the specifics of their obsolescence mitigations. Further, a challenge arises with identifying and gathering the data to inform obsolescence mitigations beyond reports that are based on known obsolescence issues rather than the required data to perform predictive analysis. Based on the themes in this research, we offer the following preliminary metrics to the community to assist with gathering more meaningful data and the assessment of these data.

$$\textit{Mean Time to DMSMS Case Resolution} = \frac{\textit{Sum Cases (Days from Case Opening to Closing)}}{\textit{Total Number of Cases Resolved}} \tag{1}$$

$$\textit{Cost of a DMSMS Case} = \textit{Sum of Labor, Materials, and Travel Costs} \tag{2}$$

$$\textit{DMSMS Cases Monthly Closure Rate} = \frac{\textit{Total Number of Closed DMSMS Cases}}{\textit{Total Number of Months}} \tag{3}$$

$$\textit{Percent of BOM Loaded in a Predicitive Tool} = \frac{\textit{Total Number of BOM Components Loaded}}{\textit{Total Number of BOM Components}} \tag{4}$$

$$\textit{DMSMS Contract Language Supply Chain Flow Down Verification} = \frac{\textit{Total Number of Verified Contracts with DMSMS Contract Language in the System's Supply Chain}}{\textit{Total Number of Contracts for a System's Supply Chain}} \tag{5}$$

Discussion and Conclusions

This research found that both the Army and industry use similar methods to mitigate DMSMS challenges with proactive obsolescence management. The findings for the first research question indicate that the Army proactively mitigates the obsolescence of C5ISR systems using a combination of focused teams, plans, training, predictive analysis tools for BOM analysis, and proactive contracting language. The findings for the second research question are similar; industry also uses a combination of focused teams, plans, training, predictive analysis tools for BOM analysis, and proactive contracting language. The findings for the third research question found the methods the Army and its industry counterparts for C5ISR systems use for proactive obsolescence mitigation are very similar.

These methods include a team approach, planning for DMSMS, predictive analysis tools, and contracting language. Note this is all predicated on adequately funding DMSMS activities. Otherwise, the monitoring and planning to mitigate obsolescence becomes dormant. This creates an environment of reactive obsolescence management, which is the most expensive and longest schedule impact approach. This research has also identified areas where additional methods have the potential to fill gaps within the current methods and practices of proactive obsolescence management. These preliminary proactive approaches to improve obsolescence mitigation effectiveness include a preliminary proactive obsolescence management model, proactive obsolescence risk mitigation framework, and proactive obsolescence mitigation metrics.

This study has several notable limitations. The first is the relatively small sample size of participants. In addition, because our research was limited to participant experiences with managing obsolescence for C5ISR systems, approaches may differ for other types of systems. In areas where we found deep experience and profound expertise, we also discovered process gaps for obtaining data and defining criteria. This prompted the development of several new methods that are presented herein (i.e., the preliminary framework, model, and metrics). However, more research and data will be needed to refine these approaches. These approaches extend the participants' insights, provide the structure to refine the approaches for broader and deeper proactive obsolescence management methods, and assist with a way of capturing data to inform future refinement of methods that can empower acquisition practitioners to successfully implement proactive obsolescence mitigation methods.

Future research could replicate this study with a larger sample size, as well as repeat this study with one or more of the other military service branches. A future study could focus on broadening the scope of this research to systems that are not C5ISR systems. Additionally, a future study could extend this research by implementing several or all of the top four proactive obsolescence management methods. Further, future research could focus on experimentation with physical or simulated data using the preliminary framework, model, and metrics.

A future study could focus on broadening the scope of this research to systems that are not C5ISR systems.

Overall, this article provides a combination of proactive obsolescence mitigation, reactive obsolescence mitigation, proactive obsolescence mitigation methods, importance of DMSMS contracting language, obsolescence management practices to avoid, a preliminary proactive obsolescence management model, framework, and metrics. The combination of the obsolescence mitigation approaches in this article provides additional tools to contribute to achieving greater system readiness, more availability, better maintainability, and lower costs for C5ISR systems.

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Author Biographies

MR. MATTHEW D. CHELLIN

is a strategic products manager at the U.S. Army Communications-Electronics Command Integrated Logistics Support Center at Aberdeen Proving Ground, Maryland. He is a PhD candidate in systems engineering at Colorado State University.

His research interests include artificial intelligence/machine learning, data science, model-based systems engineering, and product support engineering. Mr. Chellin holds a BS in Business Administration with a concentration in Economics and Finance from Monmouth University and an MPA from Columbia University.

(E-mail address: matthew.d.chellin.civ@army.mil)

DR. ERIKA E. MILLER

is an assistant professor of Systems Engineering at Colorado State University. Her research interests include human factors, modeling human behavior, safety, transportation systems, technology adoption, and technology integration. She holds a BS in Civil Engineering from Oregon State University, and an MS and PhD in Civil Engineering from the University of Washington.

(E-mail address: erika.miller@colostate.edu)

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ADOPTION OF Model-Based Systems Engineering IN TRADITIONAL DoD Systems

Capt. Patrick Assef, USAF, and Lt. Col. Jeremy Geiger, USAF

The transition to digital engineering has become a major objective within the Department of Defense (DoD). One such method is Model-Based Systems Engineering (MBSE), or the use of models to facilitate systems engineering. Most new DoD programs are being built from the ground up using MBSE. However, the question of whether MBSE should be incorporated into existing systems still lingers. Little research currently exists on the efforts required to transition existing systems to MBSE. In this article, the authors measure the effort required to transition an existing system of systems (SoS), which primarily relied on document-centric methods, to MBSE. Time efforts were measured to develop the model for the SoS, as well as the subsystems and components it contains. Additionally, existing MBSE resources that are part of the cost of transitioning to MBSE were also compiled. The research is intended to serve as a guide for program managers throughout the DoD to roughly estimate the time and costs they will incur to transition their programs to MBSE.

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Keywords: *Model-Based Systems Engineering (MBSE), Systems Modeling Language (SysML), Document-Based Systems Engineering (DBSE), digital engineering, system of systems (SoS)*

The Department of Defense (DoD) is making an unprecedented shift in the way it conducts systems engineering. Traditionally, Document-Based Systems Engineering (DBSE) has been used over the life cycle of our weapon systems. As the name implies, documents are used in DBSE to capture important system information: technical specifications, interfaces, requirements, analysis, and functions. Documents often include (but are not limited to) text files, spreadsheets, slideshows, diagrams, and/or operational views. In 2018, the Office of the Deputy Assistant Secretary of Defense for Systems Engineering introduced a new initiative, the Department of Defense Digital Engineering Strategy, to capitalize on the best systems engineering practices found in the commercial environment. This strategy was designed to move the DoD away from DBSE and toward digital engineering practices to "help ensure continued U.S. technological superiority" (DoD, 2018, p. 12).

Disadvantages of the DBSE approach have become apparent. Complex systems quickly become document-intensive and are difficult to change and sustain (p. 15). This leads to extended development and acquisition times for systems, which is not acceptable in "rapidly changing operational and threat environments, tight budgets, and aggressive schedules" (p. 1). The strategy urges the adoption of digital engineering, which is "an integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support life-cycle activities from concept through disposal" (p. 3). Compared to DBSE, digital engineering is expected to offer informed decision making, enhanced communication, increased design flexibility and adaptability, increased confidence in the system, and increased engineering and acquisition efficiency (p. 3).

One form of digital engineering being used in the DoD is Model-Based Systems Engineering (MBSE). MBSE is defined by the International Council on Systems Engineering (2007) as "the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases" (p. 15). Newer DoD systems, such as the T-7A training aircraft and Ground Based Strategic Deterrent missile

system, are being built from the ground up using MBSE. However, the majority of DoD systems were developed and fielded using DBSE methods. Program offices wishing to transition a weapon system to MBSE methods will need to determine how to do so and what resources will be needed.

> **Compared to DBSE, digital engineering is expected to offer informed decision making, enhanced communication, increased design flexibility and adaptability, increased confidence in the system, and increased engineering and acquisition efficiency.**

To support the shift to digital engineering, the Air Force recently established the Digital Transformation Office (DTO) with the goal of managing digital transformation activities in both the Air and Space Force enterprises (Alia-Novobilski, 2021). The DTO SharePoint site contains some resources for program managers to start the transition to MBSE, but the site is still a work in progress. Additionally, current literature has not captured all efforts required to transition an existing system from DBSE to MBSE. This leads to a few different research questions:

- What efforts are required to transition an existing, document-based system of systems (SoS) to MBSE?
- How can transition efforts be measured?
- What resources are available to program offices trying to transition a system to MBSE?

This research examined an existing SoS built and managed using DBSE and measured the effort needed to shift the SoS to MBSE. Additionally, this research explored what existing resources are available for program managers wishing to transition to MBSE methods.

Literature Review

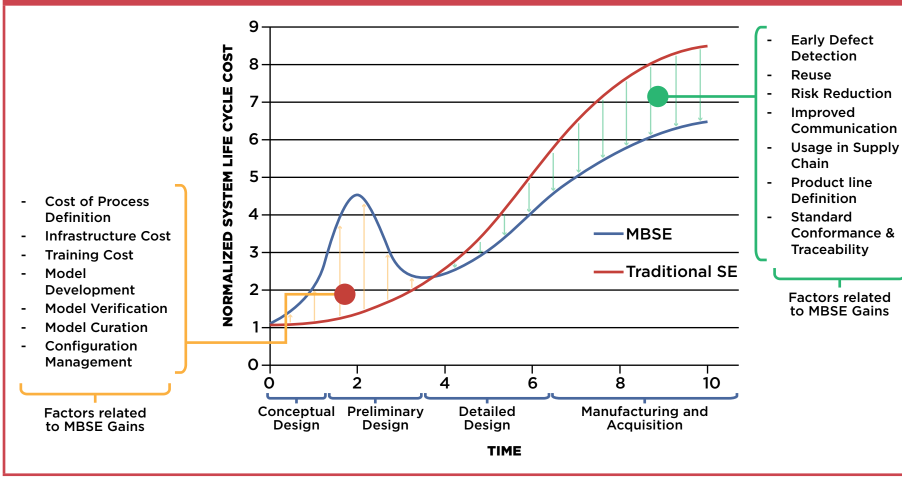
Industry's approach to systems engineering has been shifting from DBSE to MBSE over the past several years. As a result of this shift, MBSE has become an important area of research as commercial and government organizations determine how to approach the MBSE process. MBSE methods affect the entire life cycle of a system and require extensive investment in training, technology, and process changes. Stated advantages of MBSE often include reduced program costs, improved system performance, improved decision making and traceability, and decreased program risk, among many others (Carroll & Malins, 2016, pp. 45–48; Henderson & Salado, 2021, pp. 51–66; Huldt & Stenius, 2019, pp. 139–145). However, in a systematic review of 360 published papers mentioning MBSE benefits, Henderson and Salado (2021) found only two that had measured the benefits of using MBSE (pp. 57–59). Additionally, only 10% of papers observed some benefit resulting from MBSE, while the benefits mentioned in the remaining papers were only perceived or referenced from another paper (p. 59). This shows a large gap in current research to measure the benefits of MBSE and the efforts it takes to adopt MBSE.

Part of the reason for the lack of measured MBSE benefits may be due to the relative newness of MBSE methods. Examining the current state-of-practice of MBSE through surveys and interviews, Huldt and Stenius (2019) found that, on an organizational scale, no established methods exist to measure the benefits or efforts of using MBSE (p. 144). In addition, hurdles are still encountered in applying MBSE over the life cycle of larger, more complex systems. Most implementation of MBSE has been on the front end of system development, so methods and tools may not be sufficiently developed for later program management activities (pp. 139–140). Little published research is available on applying these same methods and tools to an existing system in the later stages of its life cycle. Additionally, without standards for how the effort can be measured, program managers will not know what efforts are required to transition their systems to MBSE.

Organizations are interested in adopting MBSE for their systems. NASA has published results of applying MBSE within its programs (Bayer, 2018). The DoD has also performed research on the use of MBSE to assist in creating a new system (Cole et al., 2019). However, in both of these cases and much of current MBSE research, the system was developed from the beginning using MBSE. Research on transitioning an existing system has just recently become an area of focus. Rogers and Mitchell (2021) examined the application of MBSE to the Submarine Warfare Federated Tactical Systems (SWFTS) program, a complex system of systems incorporating commercial and military systems that had traditionally used document-based methods. The SWFTS is currently undergoing sustainment activities within its life cycle and had traditionally used spreadsheets and database software to manage requirements (pp. 8–9). By transitioning to MBSE to manage and test interface requirement changes, the authors found an 18% decrease in required labor time, 9% fewer problems, 18% of problems being identified earlier, as well as associated cost reductions within the program (pp. 17–18). They also developed a metric for measuring the number of labor hours taken to make requirements modifications, where they found MBSE to take an average of 9.9 hours per requirement, down from 12.1 hours required during the legacy process (p. 13). Rogers and Mitchell (2021) show that transitioning an existing SoS from DBSE to MBSE is possible, can provide benefits to the system, and provide a metric for program managers to estimate an effort for a transition. However, this study focused solely on transitioning requirements. Transitioning other portions of a system (e.g., structure or functions) to MBSE are other areas that can be researched. Additionally, the SWFTS program is a single data point of transitioning an SoS to MBSE. More data points should be collected to confirm the results and further develop a time/cost model of transitioning a system to MBSE.

Another study by Madni and Purohit (2019) examined the economics of transitioning existing systems from DBSE to MBSE. In comparing DBSE and MBSE approaches, they found that the MBSE approach, while requiring a greater up-front investment, gave a greater return on investment later in the system's life cycle (pp. 11–13), as shown in Figure 1 (see next page). Expected gains from MBSE included earlier defect detection, risk reduction, improved communication, and reuse of models and data, all of which led to time and/or cost savings (pp. 13–14). Madni and Purohit (2019) break the costs of transitioning an existing system to MBSE into four categories: process definition cost, infrastructure cost, training cost, and model-related costs (p. 13).

FIGURE 1. MBSE AND DBSE LIFE-CYCLE COST



Note. *Source*: Madni & Purohit, 2019, p. 13

- Process definition cost is the cost of applying and generating models using a specific MBSE methodology.
- Infrastructure cost is the cost of software and equipment to perform MBSE.
- Training cost is the cost of training people on MBSE, tools, and modeling languages.
- Model-related costs are the costs that come with developing the model, including maintaining consistency, verifying the model, and configuring the model for the intended number of users.

With costs and benefits identified, users can better determine whether transitioning their system to MBSE will produce a net positive benefit.

Methods

To determine the efforts required to transition an SoS to MBSE, an existing system that relies on DBSE must be identified. The system should have >90% of its systems engineering work accomplished through DBSE processes and >90% of system information captured in documents. These criteria will result in selection of a system that relies on documents for systems engineering and has information available to develop a digital model. The system's past and present systems engineering and technical documents will need to be collected to develop the digital model. The time it takes to transition the documents to the model will be recorded for each system or component within the SoS, as well as the SoS as a whole. The goal of this research is not to provide a definitive amount of time required to transition a whole SoS to MBSE. Rather, it provides a data point from a single SoS that can—with the addition of other data points—be used to generate an estimate for the amount of time to transition a system or SoS.

All four categories of cost identified by Madni and Purohit (2019) were considered in this research. The model-related costs will be captured during the transition of the existing SoS to MBSE. To capture process definition, infrastructure, and training costs, current MBSE resources will be compiled to provide a user with available options. This list of resources provides a reference for users interested in transitioning their system to MBSE, offering them the ability to roughly estimate costs. MBSE resources will be compiled using a combination of online search engines and pre-existing lists compiled by various organizations. Important information about each resource was tabulated for the user. As stated previously, the intent of this research is not to point a user toward a specific MBSE methodology, tool, or training resource, but to provide users with information on the resources available to them. They can then estimate the effort needed to transition their organization to MBSE based on the resources that best suit them.

This research uses the Systems Modeling Language (SysML) to develop its MBSE model. SysML is a general-purpose graphical modeling-language for systems engineering, maintained by the Object Management Group (OMG). Unified Modeling Language (UML) 2.0 is the graphical-modeling language for software engineering from which SysML is derived. SysML provides a user with different diagram types to create a model. The nine diagrams can broadly be grouped into five categories: (a) package diagrams, dealing with the organization of the model; (b) requirement diagrams, detailing system requirements and their relations; (c) behavior diagrams, which model system behavior; (d) parametric diagrams, used to perform analysis

on a system; and (e) structure diagrams, which present the structure of the system, including its composition, interconnection, and interfaces (Friedenthal et al., 2015). Some of these diagrams are inherited from UML 2.0, while others are new. Cameo Systems Modeler v19.0 SP4 was chosen as the MBSE software tool for this research. Cameo allows modeling and simulation of systems in an MBSE environment and supports SysML usage. The authors chose both SysML and Cameo because of their familiarity with, and access to, the language/software. Additionally, SysML and Cameo are used in commercial industry as well as the DoD.

> **Training resources are courses intended to teach users about MBSE, whether it be general MBSE knowledge or specific language/tool application.**

The authors located an existing SoS within the DoD, which heavily relies on DBSE methods. The SoS consists of several different types of subsystems and components to connect the subsystems within the SoS. As part of an Acquisition Category (ACAT) III program, the SoS is defined by the DoD as requiring less than $200 million of total expenditure for research, development, test and evaluation, and less than $920 million for procurement. The program office that maintains this system uses a Microsoft SharePoint site as a central repository for documents. The authors used digital spreadsheets to record the number and types of documents made available for this research. The authors chose this SoS as a basis for their research because of the use of DBSE methods by the program office, number of documents about the structure of the SoS and its subsystems, and access to documentation to build the digital model. The SoS provided a good data point as all of its systems engineering work is accomplished through DBSE processes, and information is captured in documents. For the chosen SoS, this research only examined the structure of a single SoS because of constraints on time and access to information.

To begin, the researchers found lists of resources created by various MBSE organizations and used Google's online search engine to find other potential resources that were not included in the pre-existing lists. The authors searched for the terms *MBSE resources*, *MBSE software*, and *MBSE methodologies*. Information was recorded in spreadsheets. The authors then performed additional research on each resource found, such as cost to gather information about the resource. Resources were divided into three categories: methodologies, software tools, and training.

In terms of MBSE, a methodology is a combination of a process (what will be done), a method (how it will be done), and a tool (ability to do the "what" and "how") (Estefan, 2008, pp. 2–3). The methodology acts as a recipe, directing the usage of the process, method, and tool (p. 3). Software tools are software that supports MBSE modeling through a modeling language, such as SysML. Training resources are courses intended to teach users about MBSE, whether it be general MBSE knowledge or specific language/tool application.

Table 1 captures information on software resources. This information informs a user about whether or not the existing software is available and the popularity, cost, and variations. Since the prices of software regularly change as new editions and features are added, price information will be recorded using a scale of one-to-three dollar signs. One dollar sign represents a cheaper cost and three represents a more expensive cost. The price includes the one-time cost of initially purchasing the software license and the annual price to maintain a subscription. Most companies offer a subscription service to their software, allowing a user to receive new updates and versions (as long as the subscription is maintained). Without a subscription, users maintain their software license (referred to as a perpetual license), but are usually locked into the version of the software they initially purchased. Some companies also offer the ability to rent software licenses, with loss of access to the software license once the rental period ends. These aspects are captured under the "Purchase Options" category.

TABLE 1. SOFTWARE INFORMATION TO BE CAPTURED

Software	Name of the software
Company	Company that develops the software
Country of Origin	Country where the company is located
Number of Users	Numbers of users of the software
Version	Different versions of the software available, ordered from least amount of features to most
Price	Price of the software, rated on a scale of $ (low) to $$$ (high)
Purchase Options	Perpetual, rental, and/or subscription
License Type(s)	Standard, floating, or both
Modeling/Simulation	Modeling and/or simulation
Cloud Service	Does the software offer a cloud service for model storage and collaborative work?

Another option for users to consider is the type of purchase license: standard or floating. Standard licenses, also called node-locked, are tied to a single device, although some companies allow license transfers to other devices (which may come with an additional fee). While users have access to their devices, they can access the software with a standard license. Floating licenses are stored on a server and checked out when a user is making use of the software, allowing the software to be installed across multiple devices. If all floating licenses are checked out, the software will not be accessible until one of the licenses is made available again. In general, standard licenses are cheaper and better for an organization, with users and devices paired one-to-one, while floating licenses are better in larger organizations with multiple devices and users who will not be using the software at the same time.

Finally, two other features for users to consider with software are the support of simulation and a cloud storage service. Many pieces of MBSE software allow users to not only model their system, but simulate it as well. These simulations can include engineering analysis based on data values or the simulation of behaviors modeled in diagrams. Typically, the higher end variations of specific software incorporate simulation features. Whether or not the software supports simulation features is captured under the "Modeling/Simulation" category. The ability for multiple users in an organization (or across multiple organizations) to collaborate on a single model is also an important feature. Cloud storage is a method of data storage using the internet/remote servers. Multiple users can access the data on these servers without needing to be in the same location. This allows for easier collaboration and version management of models. Many companies offer some form of cloud storage and collaboration with their software, although it may come with an extra fee.

"Floating licenses are stored on a server and checked out when a user is making use of the software, allowing the software to be installed across multiple devices. If all floating licenses are checked out, the software will not be accessible until one of the licenses is made available again.

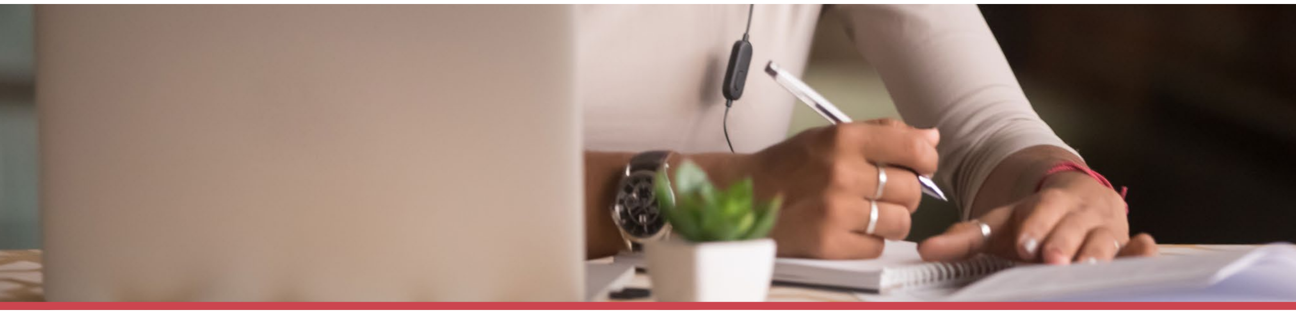


Table 2 lists the type of information that will be captured for training resources. Similar to the software table, the intent is to provide users with a list of current options and allow them to choose what best suits their needs. The training resource list will capture training resources from DoD, commercial, and university sources. Course pricing information will be captured under the "Price" category, if available. The "Language/Tool" category will be used to display whether the course focuses on a specific MBSE language and/or tool, or general MBSE. The "level" category will be used to capture the type of user for which the course is intended. Beginner courses are for those with little to no prior experience with MBSE, intermediate courses are for those with prior MBSE experience, and advanced courses are for those who are very familiar with MBSE. The course level will be based on its difficulty, as listed on the course page; or, if no level of difficulty is listed, potential students can discern the level of difficulty implied through the course description. The method of course delivery will also be included in the software table. Courses may be offered in-person or through a virtual service remotely. Two types of remote courses are offered: synchronous and asynchronous. Synchronous courses are taught in real time by a teacher with other students over a virtual network, similar to an in-person class. Asynchronous courses allow users to go through the material at their own pace.

TABLE 2. TRAINING RESOURCE INFORMATION THAT WILL BE CAPTURED

Organization	Organization that offers the course
Course	Title of the course
Price	Price of the course, if there is one
Language/Tool	What MBSE language(s) and tool(s) the course uses
Level	The MBSE skill level of the course: beginner, intermediate, or advanced
Length	Length of the course
Course Delivery	How the course is taken: in-person, synchronous remote, or asynchronous remote

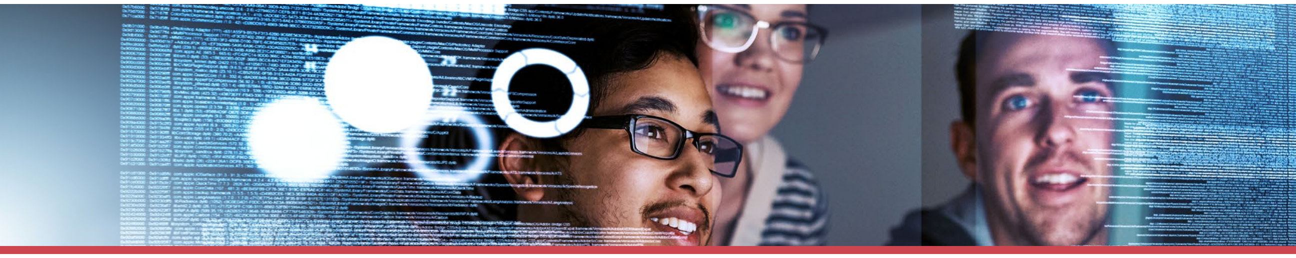
Results

The researchers created a model of the SoS using documents collected from the program office. They focused on modeling the structure of the existing SoS. Four viewpoints containing various physical, electrical, and data interfaces and interconnections within the SoS were developed in the model. Additionally, documentation of the subsystems within the SoS was recreated in the model. A more in-depth discussion on the creation and contents of the model and findings from transitioning the document-based SoS to MBSE can be found in Assef and Geiger (2021). As various documents were transitioned to MBSE, the time spent modeling was recorded. Table 3 is a breakdown of the time spent modeling. In total, 51 documents were used to model the SoS and its subsystems and components. The authors read over 5,100 pages within these documents to recreate the SoS structure within the model.

TABLE 3. TIME SPENT TRANSITIONING DOCUMENTS TO MBSE

Portion	Time Spent Transitioning to MBSE (hrs)	Time Spent Transitioning to MBSE (%)
Subsystems/Components	45.75	49.6
SoS Structure	38.5	41.7
Model	8	8.7
Total	92.25	100

In total, 92.25 hours were spent transitioning the SoS to MBSE. It took 45.75 hours to model the various subsystems/components that made up the SoS. Modeling time is further broken down into each individual subsystem and component in the discussion that follows. Modeling the SoS structure took 38.5 hours. This number included the time spent creating and connecting the different interface viewpoints, modeling connections with external systems, the physical decomposition of the SoS, and creating allocation matrices for the SoS. The remaining 8 hours were spent on general model work. This included organizing the model and determining the right type of diagrams and features to display information.



The subsystems and components within the SoS were divided into four categories (Category 1, Category 2, Category 3, and Other), based on the type and amount of documentation used to model them. For purposes of this research, a subsystem is any part of the SoS, which, when removed from the SoS, can still operate and perform a function independently. A component is a part of the SoS that cannot operate independently when removed. Using a car as an example, a smartphone used to play music over the car's radio would be considered a subsystem, as it still can independently operate and perform functions when removed from the car. On the other hand, a steering wheel in the car would be considered a component, as it serves no function when not part of the car.

> **In total, 51 documents were used to model the SoS and its subsystems and components. The authors read over 5,100 pages within these documents to recreate the SoS structure within the model.**

Category 1 included subsystems that had the most detailed documents available. These documents typically included operations and maintenance manuals, which broke down the interfaces and parts of the subsystem in copious detail. Complete structural diagrams of Category 1 subsystems were developed in the model using these documents. These diagrams contained a large amount of detail about the technical values, internal structure, and interfaces of the subsystems. Category 2 includes subsystems that had moderate detail available in documentation. They typically included documents with interface breakdowns, such as an operations manual. However, these subsystems did not have detailed part breakdowns in the documents available. As a result, the diagrams developed in the model for Category 2 subsystems detail the subsystem's interfaces but have little to no information on the internal structure of the subsystem.

Category 3 included subsystems and major components with minimal information from available documents. Typically, these subsystems/components had a one- or two-page technical data sheet with various technical values and an interface specification but little other information. Diagrams in the model for Category 3 subsystems/components feature minimal interface and structural detail.

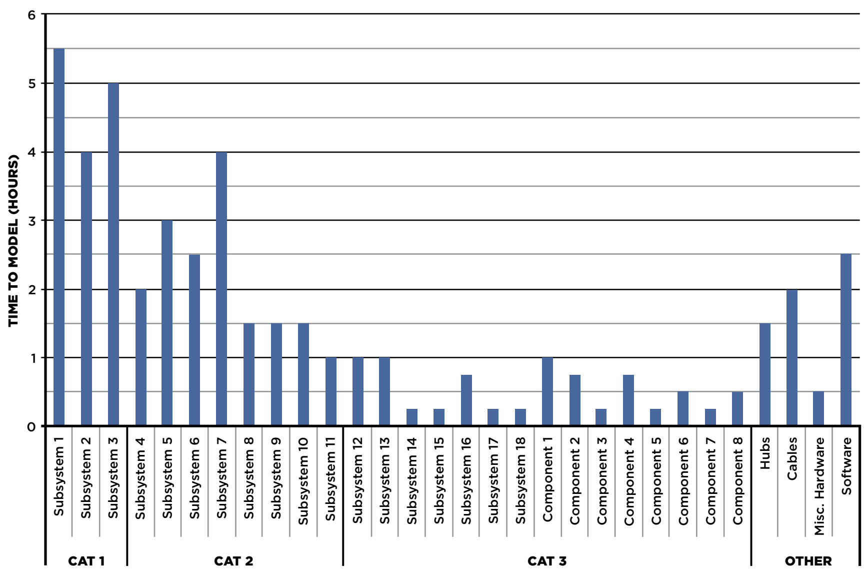
Finally, the "Other" category included groupings of minor components that did not fit well within Categories 1, 2, or 3. Groupings included cables, power/data hubs, software, and miscellaneous hardware. Each of these groups of components also had their own diagrams within the model (i.e., a cabling diagram with all of the cables, a software diagram with all of the software, etc.). The cables and power/data hubs had little documentation available, but their interfaces were derived from the subsystem and SoS interface documents. Within the SoS, 29 cables and four power/data hubs were modeled. Software included all software within the SoS. Similar to the cables and hubs, no documentation was available specifically on software. Rather, information on software was derived from engineering documentation on the SoS. Fifty distinct pieces of software were captured within the SoS. Finally, minor components that were not considered part of the subsystem, with very little technical information/documentation and only a physical interface (such as protective casing for subsystems), were grouped together as miscellaneous hardware. In total, four minor components were considered miscellaneous hardware.

The authors used 26 subsystems/components in the SoS research. This number does not include the cabling, power/data hubs, software, and miscellaneous hardware groupings in the "Other" category. Table 4 shows a breakdown of how the subsystems/components were distributed. Similarly, Figure 2 is a breakdown of the time required to model each subsystem/component.

TABLE 4. CATEGORY BREAKDOWN OF SUBSYSTEMS/COMPONENTS

Category	Description	Number in SoS
1	Documentation allowed the detailed modeling of interfaces and structure.	3
2	Documentation allowed the detailed modeling of interfaces, minimal modeling of structure.	8
3	Documentation allowed minimal modeling of interfaces and structure.	15
Other	Documentation allowed the modeling of cabling, hubs, software, or miscellaneous hardware.	4
Total	-	30

FIGURE 2. TIME SPENT MODELING EACH SUBSYSTEM, COMPONENT, AND GROUPING



A majority of the subsystems and components within the SoS fell into Category 3, while only three fell into Category 1. The decreasing number of hours required to model each subsystem/component is not necessarily representative of the total amount of time to model the subsystem/component with all documentation. It simply means more documentation was available for some subsystems. For example, subsystem 7 fell into Category 2, despite requiring the same length of time to model than subsystem 2, which fell into Category 1. This was because subsystem 7 was a more complex system than subsystem 2, with a larger number of interfaces. If documentation better detailing the structure of subsystem 7 had been available, it may have required the most time to model of all subsystems.

MBSE saved time as more subsystems were added. Subsystem 6 was one of the first subsystems modeled, so most of its elements had to be created. Subsystem 10, which had a similar number of interfaces and structural elements, took about 1 hour less to model. The time difference was because many model elements were able to be reused and repurposed in subsystem 10's diagram. As a model is developed, additional subsystems and components will take less time to develop if elements can be reused. This agrees with existing literature, which found that MBSE requires a larger up-front investment (of time and money) than DBSE but provides savings long-term, partly because of the ability to reuse assets in models (Madni & Purohit, 2019, pp. 11–13).

On average, the time to model Category 1 subsystems was 4.83 hours, Category 2 subsystems required 2.12 hours, and Category 3 subsystems/components took 0.52 hours. The decreasing average time between each category was expected, as each category has a smaller amount of documentation that was used to model the system. The hubs, cables, software, and miscellaneous hardware groupings took 1.5, 2, 2.5, and 0.5 hours, respectively. Using the number of components within each grouping, as well as the number of subsystems/components within the SoS, the average times taken to model this SoS were calculated, as shown in Table 5.

Using Table 5 as a guide, a rough estimate can be made to determine the amount of time required to transition a document-based SoS to a model. For example, if a program manager has an existing SoS with 5 Category 1, 10 Category 2, 5 Category 3, 10 different cable types, 2 different hub types, 20 pieces of software, and 2 pieces of miscellaneous hardware, it would take roughly 88 hours to transition the documents to MBSE. Of that time, 50.7 hours would be spent modeling the various subsystems and components, 30.8 hours would be spent on modeling the SoS, and 6.4 hours would be spent on general modeling.

TABLE 5. AVERAGE TIMES TO MODEL EACH PORTION OF THE SOS

Model Portion	Average Time to Model (hrs)
Category 1 Subsystem/Component	4.8
Category 2 Subsystem/Component	2.1
Category 3 Subsystem/Component	0.52
Cabling	0.07/cable
Power/Data Hubs	0.37/hub
Software	0.05/piece of software
Miscellaneous Hardware	0.12/component
SoS	1.3 per subsystem or component
General Modeling	0.27 per subsystem or component

Another factor to consider is cost. The program office managing the SoS used in this research gave a cost estimate range of $100–$200 per systems engineering hour (P. Steiner, personal communication, December 13, 2021). This cost figure lines up with Rogers and Mitchell (2021, p. 19), who used a cost estimate of $150 per systems engineering hour in their study. Based on these cost estimates, the example SoS described previously would cost somewhere in the range of $8,800 to $17,600 for the modeling work to transition from DBSE to MBSE.

These results will not be applicable to all systems. The size and complexity vary greatly from one SoS to another, and finding a one-size-fits-all metric is not reasonable. This research focused on a system from an ACAT III program. The results may be more beneficial to ACAT III programs than other programs; however, rough extractions with lower fidelity for ACAT II programs may be made. Additionally, this research only contains a single SoS data point, from which significant conclusions cannot be drawn. However, as stated in the previous section, transitioning an SoS from DBSE to MBSE is a field with minimal published and publicly available research as well as established methods for measuring effort. These results can be used as a starting point to which more data points can be added, and they can provide potential MBSE practitioners an idea of what to expect for their system or SoS.

Time to transition documents to a digital model is only one component of the costs to transition an organization to MBSE. The other components are MBSE methodologies, tools, and training for personnel, each with its own cost. In this research, the authors attempted to collect current information on MBSE methodologies, software, and training resources available to provide users with a better idea of the cost of transitioning their organization/program to MBSE.

> **Transitioning an SoS from DBSE to MBSE is a field with minimal published and publicly available research as well as established methods for measuring effort.**

Estefan (2008) captures the most heavily used methodologies and provides detailed information on what each methodology entails. The five methodologies captured by Estefan (2008) are (1) IBM Telelogic Harmony-SE, (2) INCOSE Object-Oriented Systems Engineering Method (OOSEM), (3) IBM Rational Unified Process for Systems Engineering for Model-Drive Systems Development, (4) Vitech MBSE Methodology, and (5) Jet Propulsion Laboratory State Analysis. Of these, Harmony-SE and OOSEM have free training resources available on their respective websites for learning the methodologies. Publicly available training resources for the other three could not be found.

The researchers focused on software that supports SysML in their capture of software resources, as SysML is the industry standard for MBSE. Software was found through existing INCOSE (2021) and Object Management Group (2019) webpages, and further information was gathered from the software's website. Table 6 lists the software resources compiled by this research. Thirteen software tools were found and compiled for the software resource table. Most developers of software did not publish the number of subscribed users, although each claims several large organizations use their software. Six pieces of software had multiple listed versions from which the user could choose. Versions were organized within each spreadsheet row from top to bottom, starting with the most basic and ending with the most advanced. The more advanced versions of the software offer users more features, although the exact features differ from software to software. Prices were rated on a scale of one-to-three dollar signs, with one dollar sign being <$1,500, two being $1,500–$2,500, and three being >$2,500. Pricing information was not publicly available for Rhapsody, Innoslate, SCADE Architect, or Windchill Modeler. Cameo and GENESYS provided more expensive software, while Enterprise Architect and Visual Paradigm offered options throughout the price spectrum. Astah and Software Ideas Modeler had software on the lower end of the price scale. Relatively little information was publicly available about SCADE Architect and Windchill Modeler, although their webpages both mention the support of SysML.

All companies with paid software offered standard and floating licenses as well as annual subscription plans. Additionally, the software licenses all turned into perpetual licenses (software access maintained without updates) once a subscription was discontinued. Visual Paradigm also offered the ability to rent software licenses for a 1-, 3-, 6-, or 12-month period. However, the license is not perpetual, and the user will lose software access at the end of the rental period. Finally, all paid software offered a cloud service for collaboration and the ability to model using SysML with their software. Astah, Software Ideas Modeler, and Visual Architect did not offer

TABLE 6. LIST OF SOFTWARE RESOURCES

Software	Developer	Country of Origin	No. of Users	Variation	Price (USD)	License Type	Purchase Options	Modeling/ Simulation?	Cloud Service?
Astah	Change Vision, Inc.	Japan	640,000	astah SysML	$	Both	Perpetual or subscription	Modeling	N
				astah System Safety	$	Both		Modeling	Y
Cameo Systems Modeler	Dassault Systemes (acquired from No Magic)	France		Architect Edition	$$-$$$	Both	Perpetual or subscription	Modeling	Y
				Enterprise Edition	$$$	Both		Both	Y
Capella	Multiple	France	50+ organizational users	N/A	Free	N/A	N/A	Modeling	?
Engineering Systems Design Rhapsody	IBM	USA		Architect for Systems Engineers	?	Both	Perpetual or subscription	Modeling	Y
				Designer for Systems Engineers	?	Both		Both	Y
Enterprise Architect	Sparx Systems	Australia	850,000+ licenses sold	Professional	$	Both	Perpetual or subscription	Modeling	Y
				Corporate	$	Both		Modeling	Y
				Unified	$	Both		Both	Y
				Ultimate	$$	Both		Both	Y
GENESYS	Vitech	USA		N/A	$$$	Both	Perp. or sub.	Both	Y
Innoslate MBSE	SPEC Innovations	USA	2000+ companies	N/A	?	Both	?	Both	Y
Modelio	Modeliosoft	France		N/A	Free	N/A	N/A	Modeling	N
Papyrus	CEA LIST, Eclipse Foundation	France		N/A	Free	N/A	N/A	Both	N
SCADE Architect	Ansys	USA		N/A	?	?	?	?	?
Software Ideas Modeler	Software Ideas	Slovakia		Premium	$	Both	Perpetual or subscription	Modeling	Y
				Professional	$	Both		Modeling	Y
				Ultimate	$	Both		Modeling	Y
Visual Paradigm	Visual Paradigm	Hong Kong	320,000+	Modeler	$	Both	Perpetual, subscription, or rental	Modeling	Y
				Standard	$	Both		Modeling	Y
				Professional	$	Both		Modeling	Y
				Enterprise	$$-$$$	Both		Modeling	Y
Windchill Modeler	PTC	USA		N/A	?	?	?	?	?

model simulation capability with at least one of their software versions. Three free, open source software tools were also found: Modelio, Capella, and Papyrus. All three support SysML modeling, and Papyrus supports simulation of the model. While these three software developers do not provide a space for collaborative modeling, the capability could be developed.

To capture training resources, the researchers used a list compiled by the U.S. Air Force Digital Transformation Office (Headquarters, U.S. Air Force Materiel Command, 2021), as well as training from commercial sources. As they did with the software list, the researchers focused on SysML training. Table 7 lists these training resources.

> **All companies with paid software offered standard and floating licenses as well as annual subscription plans. Additionally, the software licenses all turned into perpetual licenses (software access maintained without updates) once a subscription was discontinued.**

Training resources are offered by a variety of organizations, from commercial to DoD to universities, which include a mix of course types offered for all levels of prior MBSE experience. Many courses are available exclusively to users within the DoD community, such as those offered by the Air Force Institute of Technology and Naval Air Systems Command University. Of the courses with a specific software tool, Cameo Systems Modeler was the most common. However, many of the software companies offer training resources tailored for their software tool. Course length ranges from courses that could be completed in a few hours to semester-long university courses. Most courses offer a distance-learning option, either synchronous or asynchronous. Many of the commercial training resources also offer an in-person option, including the option for an instructor to come out to the training site of the person/organization.

This research will likely benefit program offices interested in adopting MBSE practices for their existing system but unsure whether the benefits will outweigh the cost of transition. The research is most applicable to ACAT III programs, but can be applied to any program where a transition to MBSE is desired. Using the results from this research, a program office can estimate the time it would take to transition its existing system documents

TABLE 7. LIST OF TRAINING RESOURCES

Organization	Course	Price	Language/Tool	Level	Length	Delivery
AFIT	SENG 520 Foundations of Systems Engineering	?	SysML/Cameo	Beginner	10 weeks	In-person or Virtual
	SENG 660 Advanced Principles of Engineering Design	?	SysML/Cameo	Advanced	10 weeks	In-person or Virtual
	Tailored Program-Specific Modeling and Cameo Course	?	SysML/Cameo	Varies	1–4 weeks	In-person or Virtual
Cal Tech	Model-Based Systems Engineering (MBSE) Certificate Program	$2,850	SysML	Beginner	5 days	Virtual-Sync
Dassault Systèmes	SysML Intensive with MBSE Using Cameo Systems Modeler	Paid	SysML/Cameo	Beginner	5 days	In-person or Virtual
	Teamwork Cloud Project Strategies and Best Practices	Paid	SysML/Cameo	Intermediate	2 days	In-person or Virtual
	Simulation Toolkit with Cameo Systems Modeler	Paid	SysML/Cameo	Advanced	5 days	In-person or Virtual
DAU	CENG 001 Coursera-MBSE (Model-Based Systems Engineering)	Free		Intermediate	11 hours	Virtual-Async
IBM	IBM Engineering Systems Design Rhapsody plus SysML for MBSE	Paid	SysML/Rhapsody	Intermediate	24 hours	In-person or Virtual
	Quick Starts: IBM Engineering Systems Design Rhapsody for MBSE	Free	Rhapsody	Beginner	2 hours	Virtual-Async
	Accelerated IBM Engineering Systems Design Rhapsody for Existing UML/SysML Users	Paid	UML or SysML/ Rhapsody	Advanced	24 hours	In-person or Virtual
MIT x Pro	Architecture and Systems Engineering: Models and Methods to Manage Complex Systems	$3,249	SysML	Beginner	17 weeks	Virtual-Sync
NASA	Foundations of MBSE (APPEL-vMBSEI)	Free	General MBSE	Beginner	1 day	Virtual-Sync
	Applied MBSE (APPEL-vMBSE2)	Free	General MBSE	Intermediate	2 days	Virtual-Sync
	Model Based Systems Engineering Design and Analysis (APPEL-vMBSE3)	Free	General MBSE	Advanced	3 days	Virtual-Sync
NAVAIRU	CORE-410-102 Basic SysML (101/201)	Paid	SysML	Beginner		
	CORE-420-103 Intro to SysML	Free	SysML	Beginner	4 hours	Virtual-Async
	CORE-411-115 SE Bootcamp	Free	General MBSE	Beginner	5 days	In-person
	CORE-411-116 SET for PMs and IPTLS	Free	General MBSE	Beginner	3 hours	Virtual-Async
	CORE-41B-2001 A Look Ahead at SysML v2 by Sanford Friedenthal	?	SysML	Intermediate		
	CORE-41B-200121 Language, Profile, and Framework	?	SysML	Intermediate		
	CORE-41B-200211 Cameo Collaborator-Tutorial	?	SysML/Cameo	Intermediate		
	CORE-44W-190314	?	SysML	Intermediate		

TABLE 7. LIST OF TRAINING RESOURCES (CONTINUED)

Organization	Course	Price	Language/Tool	Level	Length	Delivery
NAVAIRU (continued)	CORE-450-195 Applying Open Architecture Through MBSE for Applications at NAVAIR	?	UML & SysML	Intermediate		
	CORE-4KB-181219 Application of MBSE in the Development of UPneXt	?	General MBSE	Beginner		
	CORE-4M2-107 SysML Intensive with MBSE using CSM	?	SysML/Cameo	Intermediate	5 days	
Naval Postgraduate School	SE4930 Model-Based Engineering Course	$2,500		Intermediate	10 weeks	Virtual-Sync
	MBSE Certificate Program	$10,000		Intermediate	1 year	Virtual-Sync
PivotPoint Technology	Essential MBSE + SysML Applied	Paid	SysML/Various	Beginner	3–5 days	In-person or Virtual
	Intermediate MBSE + SysML Applied	Paid	SysML/Various	Intermediate	4–5 days	In-person or Virtual
	Advanced MBSE + SysMLApplied	Paid	SysML/Various	Advanced	3–5 days	In-person or Virtual
Sparx Services	MBSE Using Sparx EA	Paid	SysML/Enterprise Architect	Intermediate	5 days	In-person or Virtual
SPEC Innovations	IST 101 Introduction to Innoslate	Paid	LML/Innoslate	Beginner		In-person or Virtual
	IST 201 Innoslate for MBSE	Paid	LML/Innoslate	Beginner	2 days	In-person or Virtual
	IST 501 Intermediate Innoslate Application	Paid	LML/Innoslate	Intermediate	3 days	In-person or Virtual
	IST 705 Advanced Innoslate Workshop	Paid	LML/Innoslate	Advanced		In-person or Virtual
Teaching Science and Technology, Inc.	MBSE Course with Workshop	$980	General MBSE/ Innoslate	Beginner	4-5 days	In-person or Virtual
Thales	Arcadia & Capella MBSE training	Paid	Capella	Beginner	3 days	
Visual Paradigm	Visual Paradigm Essential	Free	Visual Paradigm	Beginner	5+ hours	Virtual-Async
Vitech	MBSE Tutorial	Paid	General MBSE	Beginner	2 hrs – 2 days	
	Introduction to MBSE with GENSYS	$1,995	GENESYS	Intermediate	5 days	Virtual-Sync

to an MBSE model. An engineering labor cost rate can be applied to this time value to estimate the cost of transitioning the system to MBSE. Using the MBSE resources gathered in this research, the program office can also determine approximate costs for the process, software, and training resources needed for successful MBSE adoption in their organization. Readied with all this information, the program office will have an estimate of the up-front time and cost needed to transition a program to MBSE. Each program office can then make an informed decision as to whether MBSE practices are beneficial for its system or if the costs of transition are too great. Another factor for program offices to consider is the long-term benefits of MBSE adoption, which are presented in referenced research.

Conclusions

In this article, the authors have answered the following research questions:

- What efforts are required to transition an existing, document-based SoS to MBSE?
- How can transition efforts be measured?
- What resources are available to program offices trying to transition a system to MBSE?

Using an existing DoD program that utilized DBSE, an SoS was successfully transitioned to MBSE methods, specifically a digital model using SysML. The scope of the research was limited to transitioning the structure of the SoS, as well as its various subsystems and components. To measure the effort, the time taken to transition the SoS was recorded. In total, 92.25 hours were spent transitioning the SoS to the digital model. The total time was further broken down into time used to model the subsystems and components of the SoS; time spent modeling the interconnections, interfaces, and structure of the SoS; and time spent on the general model. These three processes took 45.75, 38.5, and 8 hours, respectively. Individual subsystem and component times were further broken down and categorized based on the amount of documentation available. Because of model element reuse, the authors observed that subsystems were modeled quicker as more model elements were created. Using the recorded effort measurements, average times were computed that could provide an estimate of how long it would take to transition an existing SoS based on its number of subsystems and components. As this research has only one SoS data point, this estimate was not intended to be a parametric for application to other systems, but a starting point to which additional data points should be added.

Additionally, the research compiled tables of available methodologies, software, and training resources for prospective MBSE adopters. The purpose of collecting these resources was to provide prospective MBSE adopters with knowledge of the resources available to them, as well as information about those resources. With this information, a program office can devise a rough estimate on what type of time and cost effort will be required to transition its system to MBSE.

One limitation on this research was the size of the system studied. The system was an ACAT III program, so the results from this research may not scale to larger, more complex programs. Another limitation was the modeler used for this research. A single modeler was used to develop the digital model in this study. The modeler had prior experience with the system and was experienced using MBSE software. This research did not take into account the time needed for a modeler to gain experience with the system and MBSE software, which may result in increased model development times and costs. This research also did not take into account the time needed to prepare documents for transition to MBSE, including ensuring that information in the documents is correct, and to consult with any subject matter experts (SMEs) or stakeholders. The authors assumed the information in the documents was prepared for MBSE transition. The time contributed by stakeholders/SMEs to prepare for an MBSE transition should not be discounted in the total time required for a transition and may

significantly add to the time/cost of a transition. A program office transitioning a system to MBSE may have multiple modelers working on the model. The added need for communication between modelers (e.g., to ensure every part of a system is modeled and efforts do not overlap) may disproportionally affect the time and cost to develop the model. Future research could examine what effect having multiple modelers has in terms of cost and time.

Another limitation comes from the order in which the subsystems were modeled. The order may have resulted in a "learning curve," where the first subsystems modeled took additional time due to the authors determining the best way to capture document information in the model. As more subsystems were added, the authors became more experienced and had the ability to reuse model elements, which may have resulted in faster modeling time. The order in which the subsystems and components were modeled was not captured, so researchers cannot say whether the order was a factor in modeling time. Finally, the MBSE resources compiled in this research are limited to what was publicly available. As MBSE is an emerging field, the tools, methodologies, and training resources are subject to change.

More work can be done transitioning documents from other portions of the system to MBSE—requirements, behaviors, and engineering analysis—all of which SysML supports.

More research is needed to document additional data points of transitioning DBSE systems to MBSE. As mentioned earlier, only one data point was captured in this research. An area for future research is the transition of other existing systems to verify the results of this research. Additionally, this research transitioned one portion of the SoS to MBSE—the structure and interfaces. More work can be done transitioning documents from other portions of the system to MBSE—requirements, behaviors, and engineering analysis—all of which SysML supports. Another area for further research is the level of detail needed in the digital model. Researchers could examine the return on investment received at different levels of the model (i.e., the SoS, subsystems, and component levels) to determine how much detail is needed. In summary, this research shows that transition efforts can be measured and hopefully opens the door for performing additional MBSE transition research.

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Author Biographies

CAPT PATRICK E. ASSEF, USAF

is a developmental engineer at the Air Force Nuclear Weapons Center, Hill AFB, Utah. He received his BS in Mechanical Engineering from the University of Louisville and an MS in Systems Engineering from the Air Force Institute of Technology (AFIT).

(E-mail address: patrick.assef.1@us.af.mil)

LT COL JEREMY R. GEIGER, USAF

is an assistant professor of systems engineering in the Department of Systems Engineering and Management, AFIT. He received his BS in Electrical Engineering from Michigan State University, both an MBA and MS in Electrical Engineering from Arizona State University, an MS in Flight Test Engineering from Air University via USAF Test Pilot School, and a PhD in Systems Engineering from AFIT.

(E-mail address: jeremy.geiger@afit.edu)

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Featured Book

Start with No: The Negotiating Tools that the Pros Don't Want You to Know

Author: Jim Camp

Publisher: Crown Business/ Random House

Copyright Date: 2002, 2011

Hard/Softcover/Digital: Hard/Digital, 287 pages

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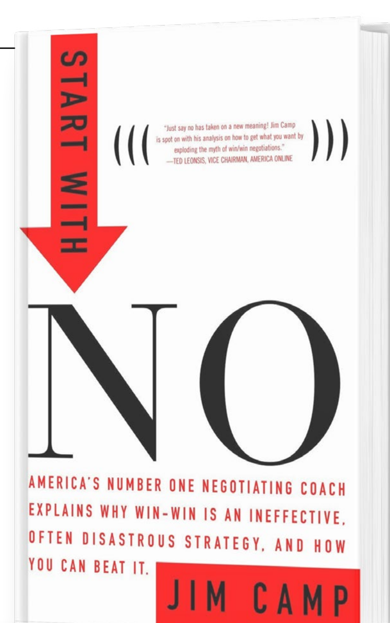
Reviewed by: John Krieger, Professor of Contract Management, DAU, Defense Systems Management College



Review:

I've read book after book about negotiations. The vast majority of them emphasize the importance of win-win negotiations, especially those out of the Harvard Negotiation Project, now the Program on Negotiation, which was founded by Professor Roger Fisher, co-author of *Getting to Yes*. My problem with most win-win books? Trouble relating to the examples (e.g., apartment leases, labor agreements, subcontracts). I negotiated government contracts (e.g., satellites, rockets, things we can't talk about) with constraints imposed by annual appropriations, the Federal Acquisition Regulation, and the Defense Federal Acquisition Regulation Supplement (e.g., budget limitations, Competition in Contracting Act, length of contract), which prevented me from creating win-win situations as a "best customer." I needed a model that more accurately reflected negotiation with those limitations, and that showed how to use what leverage we had. *Start with No: The Negotiating Tools that the Pros Don't Want You to Know* is just such a book.

In *Start with No*, Jim Camp dismisses the idea of win-win negotiations and lays out arguments for why win-win should not be the paradigm for negotiations, or at least not your paradigm. He then lays out a significantly different concept of negotiations, a system of decision-based negotiation, and the rules and the techniques to go with it. It puts me in mind of what I was told by Gail Hoke, who negotiated across the table from me for multiple satellite buys. She said, "The purpose of negotiation is not to achieve a mutually agreeable contract, but a mutually disagreeable one."

This teaser from the book jacket should give you an idea:

> For years now, win-win has been the Paradigm for business negotiation—the "fair" way for all concerned. But don't believe it. Today, win-win is just a seductive mantra for use by the toughest negotiators to get the other side to compromise unnecessarily, early, and often. Have you ever heard someone on the other side of the table say, "Let's team up on this, partner?" It all sounds so good, but these negotiators take their naive "partners" to the cleaners, deal after deal. *Start with No* shows you how they accomplish this. It shows you how such negotiations end up as win-lose. It exposes the scam for what it really is. And it guarantees that you'll never be a victim again.

Start with No includes "The Thirty-three Rules," astute observations about negotiations, the negotiation environment, and things negotiators should or should not do. Some examples:

- Your job is not to be liked. It is to be respected and effective.
- You do not need it. You only want it.
- The clearer the picture of pain, the easier the decision-making process.
- The value of the negotiations increases by multiples as time, energy, money, and emotions are spent.
- No talking.
- “No” is good, “yes” is bad, “maybe” is worse.

A book well worth the read.

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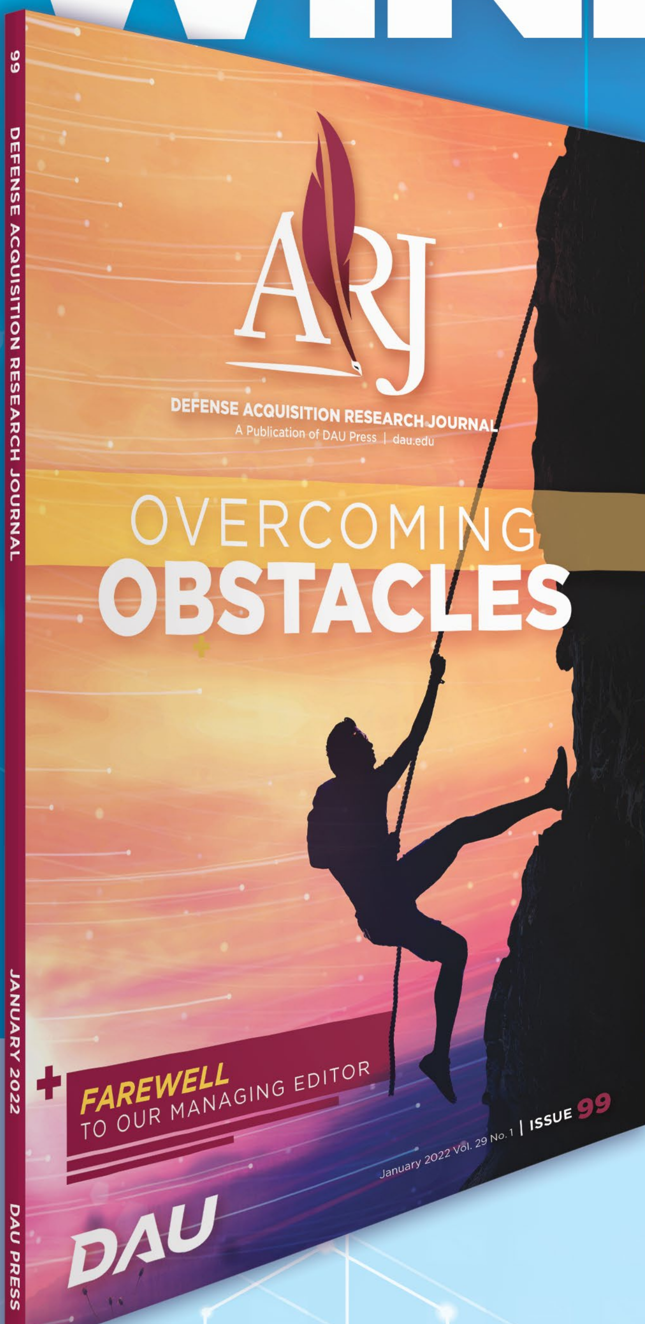

Nina Austin, Emily Beliles, Nicole Brate, and Christopher McGowan

DAU Press

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Current Research Resources in DEFENSE ACQUISITION

Acquisition Strategy

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.

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Improving Defense Acquisition: Insights from Three Decades of RAND Research

Jonathan P. Wong, Obaid Younossi, Christine Kistler LaCoste, Philip S. Anton, Alan J. Vick, Guy Weichenberg, and Thomas C. Whitmore

Summary:

Improving the U.S. Department of Defense (DoD) acquisition system—the management and development processes by which the Department acquires, develops, and sustains weapon systems, automated information systems, and services—has been an issue of sustained interest to policymakers since the beginning of the military establishment. DoD has initiated and implemented numerous actions over decades to rein in the increasing life-cycle costs and to ensure a timely delivery of these systems to meet U.S. security needs. In this report, researchers describe overarching trends that affect the defense acquisition system, outline challenges in DoD's defense acquisition process, and suggest improvements that might help address those challenges. The study is informed by open-source documents and insights from publicly available RAND Corporation research on defense acquisition, especially reports published since 1986, when a similar review of RAND research was published.

APA Citation:

Wong, J. P., Younossi, O., LaCoste, C. K., Anton, P. S., Vick, A. J., Weichenberg, G., & Whitmore, T. C. (2022). *Improving defense acquisition: Insights from three decades of RAND research*. RAND. https://https://doi.org/10.7249/RRA1670-1

MDA Laying Groundwork for New SM-3 Acquisition Strategy in FY-23

Jason Sherman

Summary:

The Missile Defense Agency is drafting a new acquisition strategy for the Standard Missile-3, eyeing a potential omnibus package that would bundle three variants of the guided-missile interceptor into a contract vehicle beginning in 2023. The contract could include options that extend for up to a decade.

APA Citation:

Sherman, J. (2022). MDA laying groundwork for new SM-3 acquisition strategy in FY-23. *Inside the Pentagon's Inside Missile Defense, 28*(4). https://www.proquest.com/trade-journals/mda-laying-groundwork-new-sm-3-acquisition/docview/2631855947/se-2

Studying Acquisition Strategy Formulation of Incremental Development Approaches

COL Robert F. Mortlock, USA (Ret)

Summary:

This study describes the challenges that acquisition professionals confront in formulating the Department of Defense's preferred acquisition strategy—incremental development. The researchers survey acquisition professionals to recommend the components of an acquisition strategy associated with a typical acquisition program undergoing program/project milestone review and approval. This work provides insights into how program managers use typical programmatic decision inputs (requirements, technology maturity, risk, urgency, and funding) to formulate the components of an acquisition strategy. The results suggest that acquisition policy should perhaps require a justification for most programs of record if an incremental development approach is not planned. Adoption of the recommended acquisition policy changes would make the

defense acquisition system more responsive to the Warfighter by fielding improved capability as quickly as possible and reducing risk associated with eventual delivery of the full required capability.

APA Citation:

Mortlock, R. F. (2020). Studying acquisition strategy formulation of incremental development approaches. *Defense Acquisition Research Journal, 27*(3), 264–311. https://doi.org/10.22594/dau.19-845.27.03

RCCTO Leader Explains Hypersonic Acquisition Strategy

Ethan Sterenfeld

Summary:

If the Army fields the Long-Range Hypersonic Weapon on schedule next October 2023, it will meet a target set by then-Secretary of the Army Ryan McCarthy in 2019: *to develop and build the country's first hypersonic missile in a little more than 4 years*. This was an ambitious goal for an Army that has struggled in recent decades to field new weapon systems on any timeline at all, especially for technology that no one could produce outside a scientific laboratory. But so far, the program has stayed on track. Success in 2023 could validate the unconventional acquisition strategy taken by the Army's Rapid Capabilities and Critical Technologies Office, which is responsible for the Army's development of a hypersonic glide body for the missile.

APA Citation:

Sterenfeld, E. (2022). RCCTO leader explains hypersonic acquisition strategy. *Inside the Pentagon's Inside Missile Defense, 28*(5). https://www.proquest.com/trade-journals/rccto-leader-explains-hypersonic-acquisition/docview/2637301484/se-2

Strategies for Acquisition Agility: Approaches for Speeding Delivery of Defense Capabilities

Philip S. Anton, Brynn Tannehill, Jake McKeon, Benjamin Goirigolzarri, Maynard A. Holliday, Mark A. Lorell, and Obaid Younossi

Summary:

Long acquisition times have been a significant concern for the U.S. Department of Defense (DoD) for decades. Providing capabilities to Warfighters in a timely manner relative to the threats faced is critical,

and DoD has undertaken various approaches through the years to reduce acquisition timelines. To reduce the time required to field operational capabilities, Department of the Air Force and other DoD organizations implemented a wide array of approaches to acquisition that are more responsive and more agile. These organizational strategies for accelerated acquisition draw on multiple approaches and techniques, including some that can reduce acquisition time compared with norms and others that might mitigate (minimize) schedule growth. In this report, the research team identifies and analyzes various approaches, assesses their suitability for different conditions and types of acquisition, and identifies implementation issues. The team also develops a selection framework and tool to help program managers and leadership identify relevant approaches.

APA Citation:

Anton, P. S., Tannehill, B., McKeon, J., Goirigolzarri, B., Holliday, M. A., Lorell, M. A., & Younossi, O. (2020). *Strategies for acquisition agility: Approaches for speeding delivery of defense capabilities*. RAND. https://doi.org/10.7249/RR4193

Army to Form Acquisition Strategy for Air Launched Effects Effort

Evan Ochsner

Summary:

The Army is taking a significant step forward in forming a program of record to modernize and distribute its unmanned aircraft systems. Air Launched Effects is intended to improve the Army's reconnaissance, surveillance and target acquisition capabilities, and lethality by using a combination of manned and unmanned aircraft within the Service's growing Future Vertical Lift ecosystem. According to a Feb. 14, 2022, announcement of an upcoming industry day and three requests for information related to the program, Army Program Executive Office-Aviation and the Unmanned Aircraft Systems Project Management Office are creating an acquisition strategy that will "guide the development and fielding of this technology over the coming decades."

APA Citation:

Ochsner, E. (2022). Army to form acquisition strategy for air launched effects effort. *Inside the Pentagon's Inside the Army, 34*(7). https://www.proquest.com/trade-journals/army-form-acquisition-strategy-air-launched/docview/2631599960/se-2

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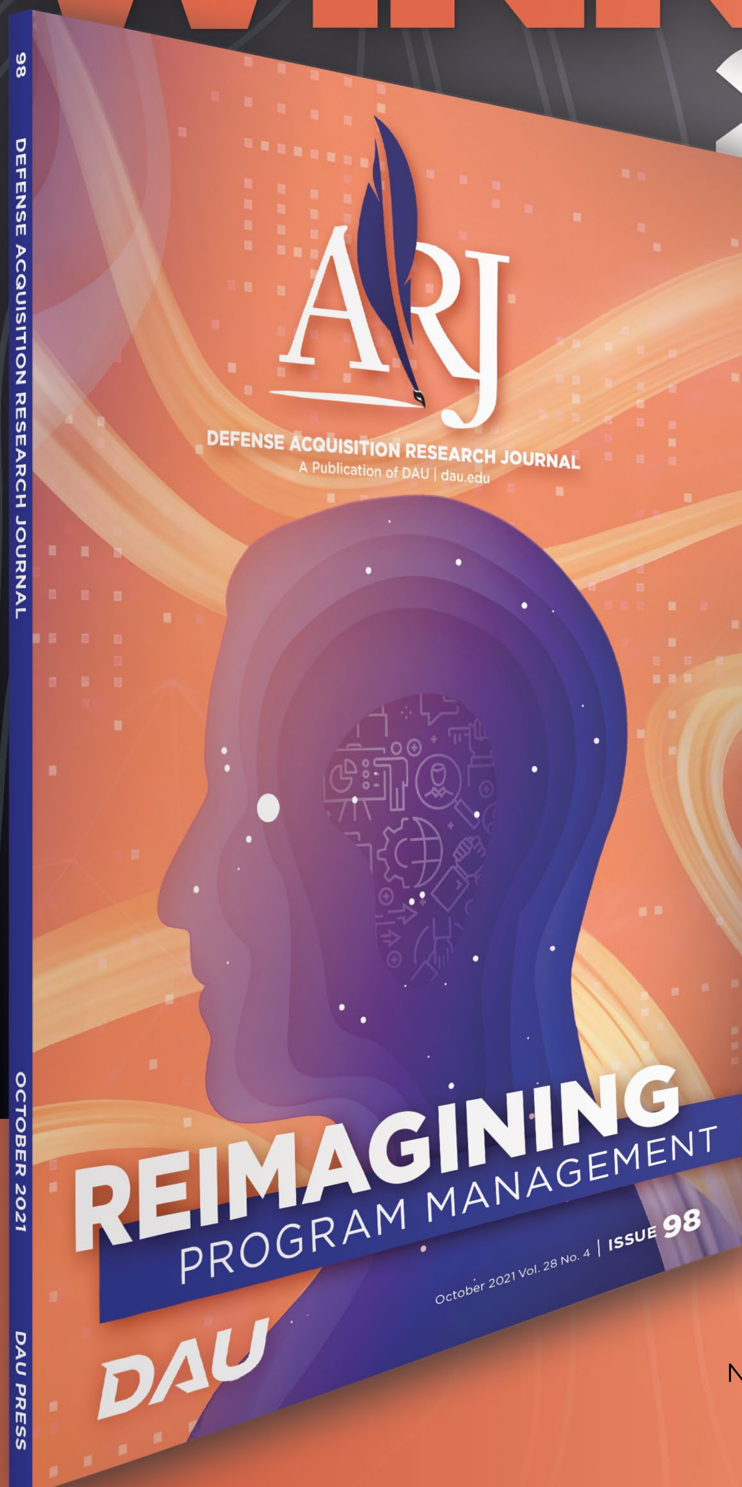

Norene Johnson, Emily Beliles, and Nicole Brate

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Defense ARJ Guidelines FOR CONTRIBUTORS

In General

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

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.

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 ARJ* articles 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.

Authors can receive 40 Continuous Learning Points (CLPs) for articles published in the *Defense ARJ* and 20 CLPs for book reviews.

Manuscripts

Manuscripts should reflect research of empirically supported experience in one or more of the areas of acquisition discussed above. *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.

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

Research Articles

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.

Empirical research findings are based on acquired knowledge and experience rather than results founded on theory and belief. Empirical research articles should do the following:

- 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 whether results are generalizable to the defense acquisition community.
- Determine whether the study can be replicated.
- Discuss suggestions for future research (if applicable).

Case Histories

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.

Each case history should contain the following components:

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

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/.

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

Defense ARJ adheres to APA style and all citations and references must be in APA format as outlined in the latest edition of the *Publication Manual of the American Psychological Association*. For all other style questions, please refer to the latest edition of the *Chicago Manual of Style*.

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January	July 1
April	October 1
July	January 1
October	April 1

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Please carefully review our Submission Guidelines, which are available on our website, before submitting your manuscript. Incomplete packages or incorrectly formatted manuscripts will be returned to the author.

Submissions should be sent electronically, as appropriately labeled files, to the Defense ARJ managing editor at: DefenseARJ@dau.edu.

In most cases, the author will be notified within 48 hours that their submission has been received. If you do not receive an acknowledgment of receipt within two working days, please contact us to ensure that we have received your submission. Following an initial review by our Executive Editor, submissions will be referred to a panel of peer reviewers. The review process consists of multiple rounds of review and can take several months.

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

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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 or rejected during the 2022 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 2023.

Ms. Cindy Baker
Professor of Contract Management
DAU

Mr. Mark Bennington
Assistant Commander for Contracting, NAVSUP
U.S. Navy

Dr. Donald Birchler
Senior Research Scientist
CNA

Mr. William A. Broadus III
Chair, Acquisition and Program Management Department
DAU, Mid-Atlantic Region

Mr. Alexander M. Brofos
Senior Principal Engineer
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Ms. Stephanie L. Contag
Professor of Contract Management/ Director of Operations
DAU, CNE

Mr. John D. Driessnack
Professor, Defense Systems Management College
DAU

Dr. William T. Eliason
Director
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DE&S Specialist Fellow in International Cooperation
U.K. Ministry of Defense and Cranfield University

CAPT Geoff Gagnier (USCG, Ret.)
Principal
The MITRE Corporation

Mrs. Emily Gallagher
Contracts Analyst
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Dr. Thomas Groesbeck
Lead Economist
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Dr. James Hasik
Senior Research Fellow
George Mason University

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Dr. Michael A. King
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Acquisition Specialist
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Professor, Systems Acquisition Management
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Professor of Program Management
DAU, CNE

Mr. Jeffrey Nolan
Principal Enterprise Solution Architect
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Research Staff
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Dr. Alexander Odeh
Principal Program Manager
The MITRE Corporation

Mr. David Riel
Professor of Acquisition Management
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Dr. James Roche
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Dr. Michael A. Rodgers
Professor of Contract Management
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Dr. Susan Rose
Research Staff Member
Institute for Defense Analyses

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The MITRE Corporation

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DAU

Dr. Marcus Smith
Lead Aerospace Engineer
The MITRE Corporation

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Dr. David M. Tate
Senior Defense Analyst
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Director of Defense, Industries, and Society Program
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