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DEFENSE ACQUISITION RESEARCH JOURNAL

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LEADING CHANGE

DAU

ISSUE 105

October 2023 Vol. 30 No. 3

ARTICLE LIST

ARJ EXTRA

DEFENSE ACQUISITION RESEARCH JOURNAL

A Publication of DAU Press | dau.edu

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

ISSN 2156-8391 (print) and ISSN 2156-8405 (online)
DOI: https://doi.org/10.22594/dau.102023-105.30.03

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

DEFENSE ACQUISITION RESEARCH JOURNAL
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Cost Overrun Optimism: Fact or Fiction?

Maj David D. Christensen, USAF (Ret.)

The author examines cost overrun data on 64 completed acquisition contracts. The results reveal excessively optimistic overrun projections throughout the life of the examined contracts despite project type and the military services managing the contracts.

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FROM THE CHAIRMAN AND EXECUTIVE EDITOR

Dr. Larrie D. Ferreiro

The theme for this issue is "Leading Change." The subject of change leadership not only reflects this issue's Current Research Resources in Defense Acquisition, it also underscores several of the articles in this journal, as well as the book reviewed in these pages.

The first article is "Deconstructing the Software Factory: A Practical Application of Interorganizational Network Analysis," by Capt Zachary O. Ryan, Mark G. Reith, and Lt Col Clay M. Koschnick. The authors present a case history that examines an emergent DoD software factory using network analysis, which captures economic and social relationships through the observation of exchanges. This type of analysis can be used to understand and visualize the interorganizational networks of nontraditional DoD software organizations, which are increasingly becoming part of the defense acquisition ecosystem.

The second article, by Matthew D. Chellin and Erika E. Miller, is titled "Frustrated With Obsolescence—Try Changing Your Mental Model." In it, the authors discuss the results of extensive interviews with U.S. Army acquisition practitioners regarding their mental models of obsolescence management. The results highlight how changing from reactive obsolescence management to risk-based proactive obsolescence management decreases the obsolescence risk of a system.

The third article is "Cost Overrun Optimism: Fact or Fiction?" by Maj David D. Christensen, USAF (Ret.), which was originally published in the *Acquisition Review Quarterly* (the prior name for the *Defense ARJ*) issue in winter 1994, and reprinted in *Defense ARJ,* Issue 74 in 2015. The author identified systematic underestimating of cost growth, and systematic overestimating of resource availability, as major contributing factors to inaccurate and unrealistic cost estimates. Even though recognized over 20 years ago, this dilemma remains a major source of inconsistency between plans and outcomes in defense acquisition and continues to impact efforts to reform the DoD's development and procurement infrastructure. The problem of cost overrun optimism will be the subject of a book review in this journal in the coming months.

This issue's theme, "Leading Change," is the inspiration for its feature section on Current Research Resources in Defense Acquisition.

The featured work in the Defense Acquisition Professional Reading List book review is *Leading With AI and Analytics: Build Your Data Science IQ to Drive Business Value* by Eric Anderson and Florian Zettelmeyer and reviewed by Philip Broyles.

We take this opportunity to bid farewell and congratulations to Michael "Mike" Shoemaker on his recent retirement. He has culminated a 36-year professional writing/editing career, 10 of which were devoted to providing editorial support to the DAU Visual Arts and Press as managing editor of the predecessor to the current *DAU Course Catalog*, followed by his service as interim managing editor of the *Defense ARJ* during 2023. Mike is a consummate professional and a published author. We wish him the best as he embarks on a new chapter of his life.

Also in this issue, we feature career highlights of this journal's Visual Arts and Press director, Greg Caruth, a visionary and talented artist and sculptor. Greg died suddenly June 28, 2023.

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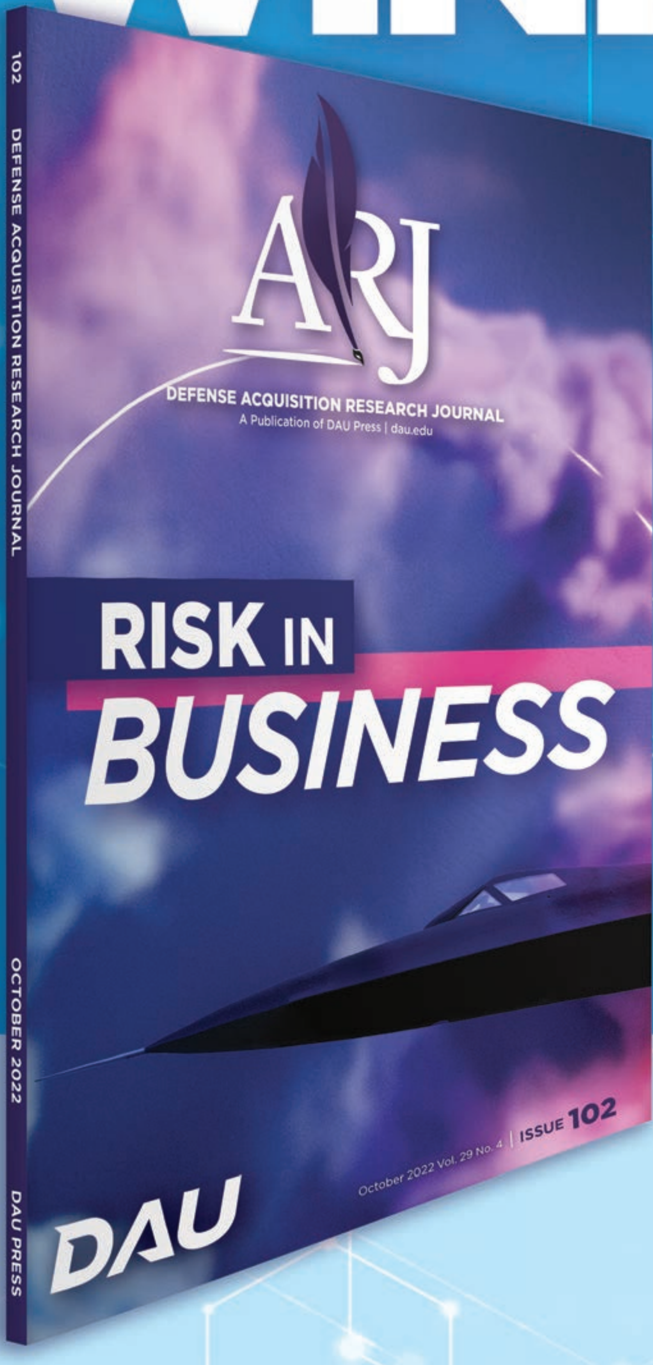

Emily Beliles, Norene Johnson,
and Nicole Brate

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Research Agenda 2023

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

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

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

Affordability and Cost Growth

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

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

Industrial Productivity and Innovation

Industry insight and oversight

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

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

Independent research and development

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

Competition

Measuring the effects of competition

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

Strategic competition

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

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

Effects of industrial base

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

Competitive contracting

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

Improve DoD outreach for technology and products from global markets

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

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

Comparative studies

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

Cybersecurity

General questions

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

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

Costs associated with cybersecurity

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

Acquisition of Services

Metrics

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

Industrial base

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

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

Industry practices

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

Make/Buy

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

Category management/strategic sourcing

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

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

Contract management/efficacy

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

Policy

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

Administrative Processes

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

Human Capital of Acquisition Workforce

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

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

Defense Business Systems

Organizational structure and culture in support of Agile software development methodologies

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

Defense Acquisition and Society

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

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

We're on the Web at:
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ISSUE **105**
OCTOBER 2023
VOL. 30 NO. 3

Image designed by Ken Salter

DECONSTRUCTING THE SOFTWARE FACTORY:

A Practical Application of Interorganizational Network Analysis

Capt Zachary O. Ryan, USAF, Mark G. Reith, and Lt Col Clay M. Koschnick, USAF

Over the past 5 years, the number of DoD software organizations that employ nontraditional organizational structures has increased. These organizations, commonly referred to as software factories, often employ the network-based organizational structures found within high-technology industries. This article details ways in which network analysis techniques can be used to create a big picture view of these nontraditional organizations. Drawing on methodologies employed by network researchers, the authors develop and present an interorganizational analysis process that highlights a program's social and economic structures. Following the case history approach, they demonstrate the applicability of this approach by analyzing an emergent DoD software factory. Throughout the article, the authors discuss how network principles and accessible analysis techniques can be applied to real-world challenges faced by modern, network-based DoD organizations. Finally, they conclude by presenting the results of their analysis and a framework that the acquisition community can use to analyze nontraditional programs.

DOI: *https://doi.org/10.22594/dau.22-900.30.03*
Keywords: *interorganizational network, Interorganizational Network Analysis (ION-A), software factory, network analysis techniques, nontraditional software programs, ties, relationships*

Program managers (PMs) have various assessment and tracking tools at their disposal designed to provide actionable insights into the cost, schedule, and performance of acquisition programs. Existing tools such as Earned Value Management, Work Breakdown Structures, and Technical Performance Measures (Driessnack, 2017) offer valuable insight into the internal activities of acquisition organizations while helping PMs monitor and control program dynamics. However, these tools do not provide direct insight into the social and economic interactions that shape the organization's overall structure. To understand the bigger picture, PMs must rely on alternative information sources like organizational charts, employee interviews, and established institutional knowledge. Understanding the people, processes, and program perspectives that comprise an acquisition program is central to the core responsibilities of a PM and the overall success of the program; to that end, DoD has created and published guidance for PMs (DAU, 2022a, 2022b). While this guidance is applicable to most defense programs, its underlying assumption is that programs will follow the traditional structures outlined within the Defense Acquisition System (DAS).

Traditional program structures, such as those outlined within defense acquisition guidance, are hierarchical with predefined relationships and dependencies, making them relatively straightforward for the PM to navigate. When organizations cannot be easily defined by these hierarchical structures, as is the case with the DoD's software factories (Ryan, 2023), they can be referred to as nontraditional. The structures of nontraditional organizations can be difficult to navigate because their relationships and dependencies may not be as well-defined or documented, making it challenging for the PM to gain insights into the program's social and economic connections. This raises the question: If existing guidance is insufficient for nontraditional programs, how can the PM begin to understand the organization's structure and develop a strategic perspective? The more limited context of DoD software programs poses a more specific problem: *How can PMs assess the interorganizational structures of nontraditional software organizations?*

In this article, the aim is to address the challenge of understanding the structures of nontraditional programs by proposing and demonstrating a method of analysis that captures and visualizes interorganizational networks. Specifically, a methodology called Interorganizational Network-Analysis (ION-A) is presented, which utilizes multiplex, egocentric network analysis techniques[1] to capture the social and economic relationships of a program of interest.

Designing a network analysis study is a complex undertaking that requires the researcher to consider multiple attributes, data collection techniques, and measurement approaches prior to conducting an analysis (Provan et al., 2005). Combined with the fractured and difficult-to-navigate nature of network analysis (Popp et al., 2014), this can present a barrier to those seeking practical network analysis techniques to better understand their organizations. ION-A addresses this issue by defining the scope of the study, the types of networks captured, and the techniques of analysis to specifically assess nontraditional DoD software programs. Demonstrated through the analysis of the social and economic structures of a DoD software factory, this approach is intended to streamline the network analysis process and make it more accessible to PMs.

By applying the proposed ION-A process, the PM will be able to identify key relationships, dependencies, and channels of communication critical to the program's success, enabling better decision-making and resource allocation, and addressing potential issues arising from the program's unique structure. These factors are particularly relevant considering the DoD's emphasis on improving software acquisition processes and improving interorganizational trust and collaboration within its software factory ecosystem (DoD, 2023). The software factory, with its relatively flat organizational structure, is a prime candidate to demonstrate the utility of ION-A in assessing and understanding the nuances of a program's social and economic connectivity. The article concludes with a discussion of the research implications, a list of strategic analysis questions, areas for future research, and applicability of the ION-A approach to other nontraditional defense programs.

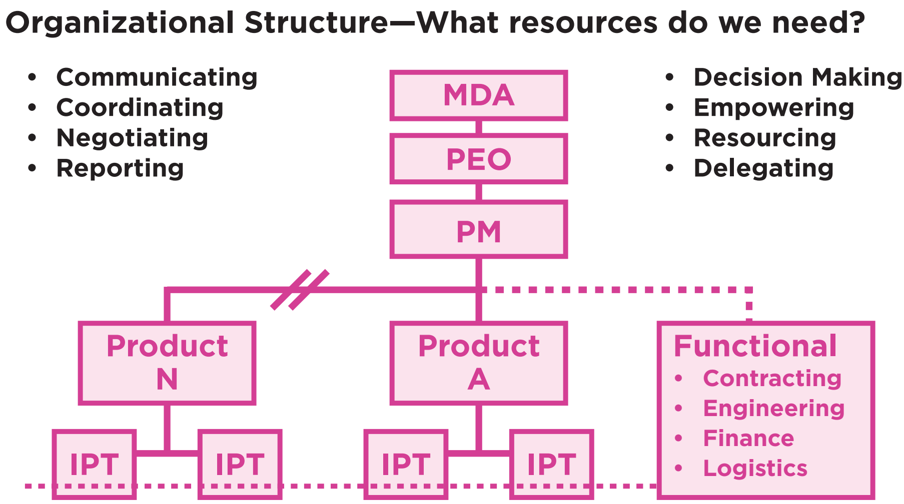
By applying the proposed ION-A process, the PM will be able to identify key relationships, dependencies, and channels of communication critical to the program's success ...

Background

DoD software factories often adopt the network-based interorganizational structures commonly found in high-technology industries (Ryan, 2023). These structures influence the economic and social relationships among organizations differently than those defined by traditional acquisition program boundaries. As a result, nontraditional programs do not always align with the established hierarchical structures outlined within the DAS. This case history analyzes one such program, a nontraditional Department of the Air Force (DAF) software factory, using a process called ION-A. This background section introduces the concept of interorganizational networks by explaining how they relate to familiar organizational models. It then describes their composition and explains how interorganizational networks can be used to visualize the economic and social relationships of an organization. Finally, this section closes by introducing the ION-A process as a method to characterize these relationships.

Visual models of interorganizational structures allow acquisition practitioners to easily draw on past experience and training to gain a baseline understanding of the behaviors and dependencies of a target organization. To illustrate this effect, we break down Figure 1, which depicts a common organizational structure composed of boxes and lines representing entities and their relationships. Because the structure of boxes and lines is easily recognizable and familiar to practitioners, the roles, motivations, and influences of the depicted entities can be assumed even if not explicitly stated on the diagram. Additionally, the basic economic and social interactions between entities can be inferred. Figure 1, in its simplicity, begins to frame the big picture of a program by invoking a familiar structure by which to understand economic and social relationships. However, when organizations do not follow these established patterns, the underlying assumptions regarding the economic and social relationships inferred from the hierarchical structure may no longer be valid. Therefore, additional steps should be taken to deliberately characterize the behaviors and patterns of exchange that were previously assumed or inferred.

FIGURE 1. ORGANIZATIONAL STRUCTURE



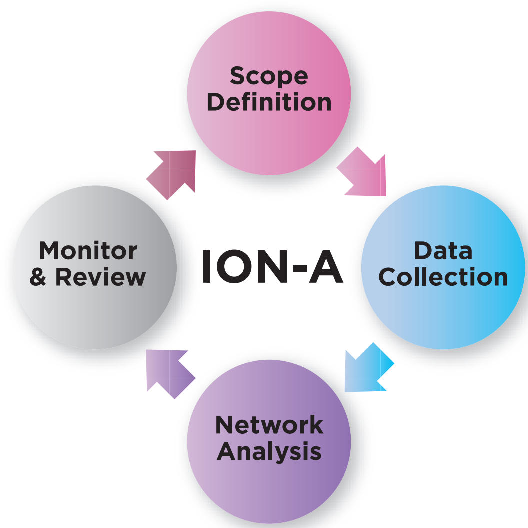
Note. DoD literature is primarily oriented to acquisition programs that follow formally defined hierarchical structures. In this chart, financial resourcing is implicitly tied to the PEO and MDA. Nontraditional programs like software factories can exhibit alternative structures that do not align with this framework. As a comparison, the PM of a traditional program may request additional funding through formal channels, while the PM of a software factory may primarily seek funding directly from customers or partner organizations. From *Program Manager (PM) Toolkit*, by J. Driessnack, 2017 (https://www.dau.edu/tools/Lists/DAUTools/Attachments/143/Program%20Manager%20Toolkit.pdf).

IPT = integrated product team; PEO = program executive officer; PM = program manager; MDA = milestone decision authority.

The generic program structure depicted in Figure 1 provides a visual representation of the primary interorganizational relationships of a program. If this representation was expanded to represent all organizations that interact with the program, it would begin to depict the program's network. By adding detail and defining the lines to represent relationships between the entities, we can formally define the resultant representation as the program's *interorganizational network*. An interorganizational network can be depicted as a collection of nodes, representing organizations or actors, and ties (also referred to as links or edges), representing relationships (Brass et al., 2004; Provan et al., 2005). These relationships, which can be observed through exchanges,[2] can be further categorized by type. Economic relationships can be observed by identifying exchanges of money and goods and services. Social relationships can be observed by identifying exchanges of information. When multiple types of relationships are represented within an interorganizational network, the network is defined as *multiplex*. When viewed holistically, this collection of nodes and ties provides a model of the organization's economic and social structures that can be analyzed.

Modeling and analyzing an organization's interorganizational network can be accomplished by conducting an ION-A. This 4-step process, depicted in Figure 2, outlines how practitioners can deliberately capture and visualize the interorganizational networks of their programs; these networks can then be analyzed using established network methods and by employing a deliberate assessment approach designed to facilitate strategic thinking. The following sections further define the ION-A process and demonstrate its application in a case history analysis of a DAF software factory.

FIGURE 2. INTERORGANIZATIONAL NETWORK ANALYSIS



Note. This 4-step process can be used to develop a big picture view of an organization. ION-A focuses on understanding the social and economic relationships of a target program by visualizing exchanges of money, goods and services, and information.

Situational Awareness Approach

To demonstrate how the ION-A process can be utilized to better understand nontraditional software programs, we embedded ourselves within a DAF software factory that could not be easily characterized via the formally established structures outlined within the DAS. To prepare for this case history, develop a contextual understanding of the organization's patterns of behavior, and establish trust, we observed the daily stand-up meetings of the software factory leaders for 3 months. This approach simulates the experience of someone new to the organization and suggests that practitioners do not need extensive experience within the program to conduct a meaningful analysis.

The software factory analyzed for this case history has existed for 1 year; it has no formally defined military or civilian manpower requirements. Instead, this organization consists of participants from partnering organizations who have volunteered to manage and grow the software factory. Its purpose is to provide a specific niche of goods and services in the form of consulting services, design services, educational outreach, application development, and systems development and maintenance to external customers.

Since the software factory is in the early stages of growth, it relies heavily on organizations within its local network to supplement core functions such as contracting, finance, and legal services. This organization also maintains autonomy and control over its assets and has been formally recognized by the DAF Chief Software Office (CSO) as a software factory. Programmatically, this software factory operates outside of existing acquisition pathways and does not have the compulsory reporting requirements of a formal program.

Many of the strategies employed by the software factory of interest are in direct alignment with the principles outlined within DoDI 5000.87, Operation of the Software Acquisition Pathway (DoD, 2020, pp. 11–12). The software factory's use of existing enterprise services and contracts, its employment of a modular contracting strategy, and its stakeholder-centric alignment are all considered key elements of a modern software program operating within the new software acquisition pathway. Collecting information on software factories was challenging because many candidates were uneasy about sharing organizational information. We addressed this concern by nonattribution.

Step 1—Scope Definition

Step 1 in the ION-A process is to define the scope of analysis, which begins by defining the nodes and ties of the interorganizational network. Nodes will exist in all organizations that interact with the program, and ties will represent relationships between those organizations. When defining nodes, the specific boundaries of the individual military organizations they represent will need to be considered based on the size and environmental context of the program of interest. To maintain a strategic focus in this analysis, military organizations were aggregated and represented as nodes at their respective branch or squadron levels. Three types of ties, representing both economic and social relationships, are defined using the exchange variables: goods and services, financial resources, and information. A detailed definition of these variables is included in Table 1.

TABLE 1. NETWORK VARIABLES OF EXCHANGE

Exchange Variable	Definition	Relationship Type
Goods & Services	*The transfer of goods & services from one organization to another.*	*Economic*
Financial	*The transfer of money from one organization to another.*	*Economic*
Information	*The active and deliberate transfer of meaningful information, knowledge, communication, or coordination where one or both parties benefit.*	*Social*

Note. The variables (goods and services, financial, and information) were selected based on the findings of recent research into the structures of software factories (Ryan et al., 2022) and research on multiplex economic networks (Maghssudipour et al., 2020).

Step 2—Data Collection

The second step in the ION-A process involves collecting and organizing data. Data collection presents a significant challenge in the ION-A process, but it can be divided into two primary tasks: identifying nodes and identifying ties. Node identification starts with generating a list of all known organizations that have interacted with the program. This initial list can be compiled from various sources, such as internal websites, existing documentation, or employee interviews. In the analysis of the software factory, the list was created by identifying organizations mentioned within Confluence, the software factory's internal knowledge management system. Each organization was categorized by affiliation as government, industry, or working group, and organized in a matrix format using Excel. Figure 2 illustrates the creation, organization, and interpretation of a matrix.

Upon creating a matrix, the next step is to identify interorganizational exchanges (Figure 3). Since a consolidated data source containing a comprehensive listing of exchanges is unlikely to exist, data collection should be conducted through semistructured interviews or brainstorming sessions with experienced personnel, using the matrix as a reference.

FIGURE 3. A SOCIOMETRIC MATRIX

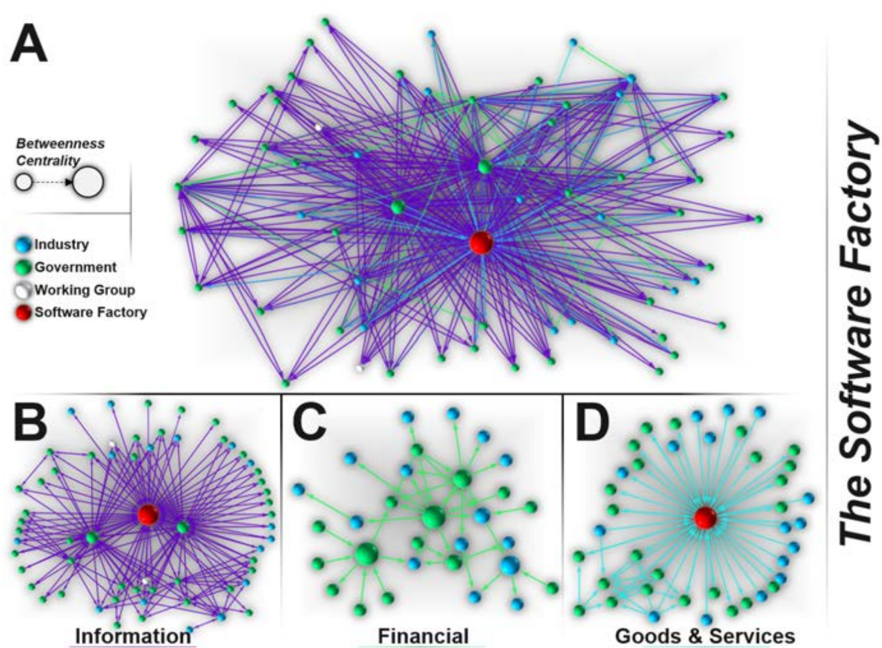
	Software Factory	Organization A	Organization B	Organization C	Organization D	Organization E
Software Factory				I	I, S	I, S
Organization A	S					
Organization B	S					
Organization C	I					I
Organization D	I					I
Organization E	I, S			I	I	
Organization F	I, S					I
Organization G	I					I, F
Organization H	I					
Organization I	I					
Organization J	I					

Note. The Sociometric Matrix can be used to capture exchanges between organizations. Organizations identified in the roster are organized in the first column and duplicated in the first row. Exchanges between these organizations are then noted within each corresponding cell of the matrix. The matrix is interpreted by reading "column A sends (money, information, goods and services) to Row 1." Example: The software factory sends information and services to organization D.

In this case study, a series of video interviews were conducted with software factory leadership to identify interorganizational exchanges. The matrix served as a guide and tool for documenting individual exchanges. The interviewees were asked to provide information on exchanges between organizations at each intersection within the matrix. All exchanges were evaluated for directionality. The matrix was completed after four interviews, and responses were validated by reviewing the video recordings. Inconsistent or unclear responses were addressed in subsequent interviews. The final matrix consisted of 62 organizations and their exchanges.

Once the data are collected, they must be converted to a network format for analysis. Various existing open-source network tools can be employed for this task. In this case study, the finalized matrix was processed using the open-source network graphing software *Gephi* (Bastian et al., 2009) and *Cystoscope* (Shannon et al., 2003). Step 2 is considered complete once the data have been initially processed using network graphing software. The networks of the software factory are depicted in Figure 4. The composite network (4A) is generated by integrating the three variables of exchange: information (4B), financial resources (4C), and goods and services (4D) into a single model.

FIGURE 4. COMPOSITION OF SOFTWARE FACTORY NETWORKS



Note. Four separate interorganizational networks were generated from the exchange variables, goods and services, financial, and information, collected in Step 2 of the ION-A. The software factory's composite network consists of government (69.3%), industry (25.8%), and working groups (3.2%), totaling 62 organizations. These networks provide a visualization of the economic and social structures of the program, which are analyzed in step 3 of the ION-A process.

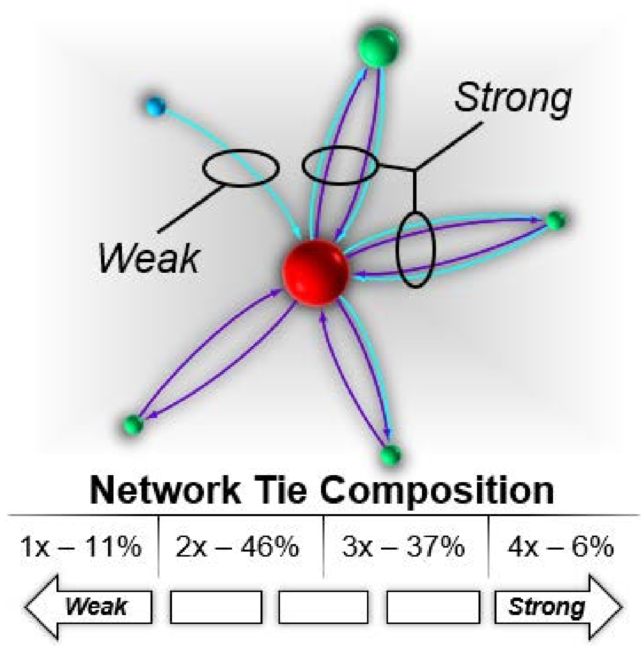
Step 3—Network Analysis

The third step in the ION-A process involves analyzing the interorganizational network of the software factory. This stage focuses on evaluating four strategic areas: relationship strength, organizational influence, exchange patterns, and communities of interest. Table 3, presented in the conclusion, provides a summarized assessment framework that encompasses these four areas of interest along with assessment questions and common network indicators. The following discussion addresses these four areas.

Relationship Strength

The analysis begins at the composite network level (4A) by evaluating the strength of relationships among organizations using the concept of multiplexity. The existence of multiple types of ties (i.e., social and economic) between entities is generally believed to indicate greater strength and durability of the relationship (Granovetter, 1973; Perry et al., 2018). By counting the ties between nodes, a basic assessment of strength can be determined. More ties suggest a stronger relationship, while fewer ties indicate a weaker relationship (Figure 5). Critical relationships can be identified manually or with network analysis software for a comprehensive assessment of the entire network.

FIGURE 5. MULTIPLEXITY AND TIE STRENGTH



Note. Tie strength for the composite software factory network was assessed using a multiplex approach. Individual exchanges between nodes were counted and summed to provide a relative measure of exchange-relationship strength.

The software factory's network predominantly consists of ties with medium relative strength, with only 6% of ties reaching the strongest threshold. These ties, representing shared, reciprocal relationships, mainly exist between the software factory and its partnering organizations. Notably, this tie pattern is also present between the sample software factory and a government platform provider where a two-way exchange of services takes place. The weakest ties within the software factory network are primarily informational, with unidirectional reporting relationships serving as examples of weak ties.

Evaluating relationship strength offers valuable insights into common organizational interactions. By engaging in different types of exchange, strong ties can be intentionally established. As the organization matures, weak links can be identified and deliberately strengthened. Strategic social partnerships can be reinforced through economic exchange. For instance, the software factory provides software services at no cost to an organization controlling access to informational resources, which strengthens the software factory's relationship with an influential organization. This leads to the next area of analysis: organizational influence.

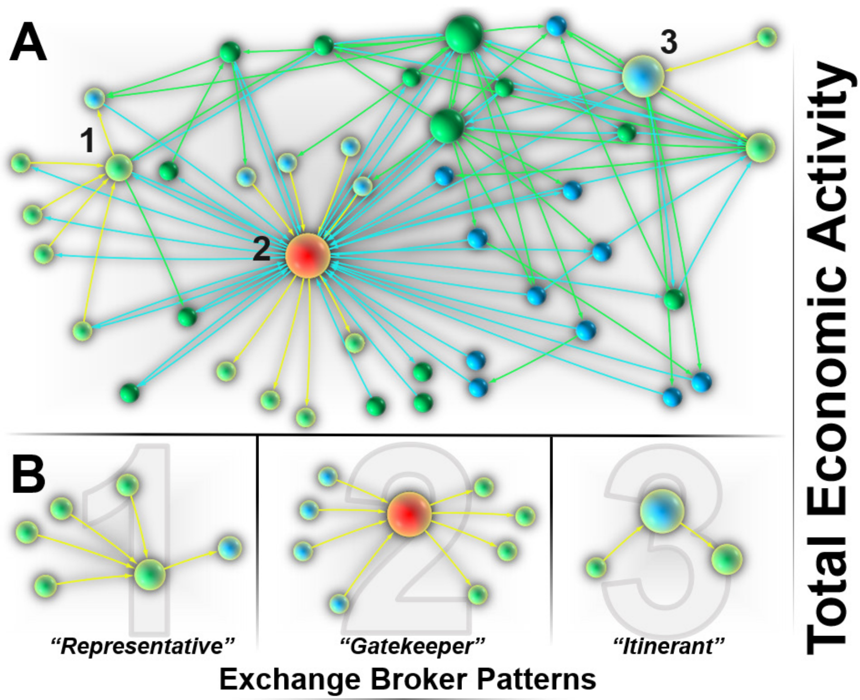
One notable observation is that the flow of financial resources through the network is varied; the software factory is funded by customer organizations rather than by a centralized source.

Organizational Influence

Most practitioners are familiar with the authoritative power structures that exist within a traditional hierarchy. However, in situations where these structures are less well-defined, an organization's positional power can often play a more significant role in its ability to exert power and control over the program. Positional power structures can be identified by analyzing centrally positioned organizations, critical resource flows, and exchange brokers within the program's interorganizational network. By considering these factors in conjunction with the program's requirements, it is possible to identify influential organizations.

To identify centrally positioned organizations, the composite interorganizational network of the software factory was assessed for betweenness centrality, which is represented on the network models using node size. Betweenness centrality measures how often a node exists on the shortest path between other nodes within the network, aiding in identifying nodes that have influence over the flow of information within the network due to their position (Freeman, 1977). While different types of centrality measures can be used, betweenness centrality was chosen because of its applicability to both sociocentric and egocentric network data (Marsden, 2002). The two primary partner organizations of the software factory had the highest centrality, indicating their importance relative to other organizations in the network. When assessing the economic network for centrality (displayed in Figure 6A), additional influential organizations can be identified.

FIGURE 6. ECONOMIC NETWORK OF THE SOFTWARE FACTORY



Note. This economic network is generated by combing the exchange variables financial and goods and services. In addition to identifying centrally positioned organizations, three broker roles were deemed notable within the software factory economic network: the representative, the gatekeeper, and the itinerant. Tracking these brokers is an essential component of identifying and controlling external program risks.

The economic network generated from the financial resources and goods and services exchange variables provides valuable insight into the flow of resources between organizations. One notable observation is that the flow of financial resources through the network is varied; the software factory is funded by customer organizations rather than by a centralized source. To utilize these resources, the software factory relies on multiple contract vehicles owned by other organizations within its network. The organizations that manage and maintain these vehicles function as economic hubs. Because they control the flow of resources from customers to the software factory, they have positional power. Another observation on the flow of goods and services is largely centered around the software factory, with additional convergence occurring around the organizations acting as brokers, which are organizations that help coordinate exchange.

The software factory network (highlighted in Figure 6B) embodies three primary broker roles: the representative, the gatekeeper, and the itinerant. These roles are defined based on their affiliation and positioning within the network (Gould et al., 1989). The *representative* broker emerges when a government organization coordinates a transaction from another government organization to an industry partner. In this scenario, one government organization *represents* the other. This situation occurs when customers fund a contractor through a third-party government organization. The *gatekeeper* role exists when a government organization purchases services from a third party via a contractor organization. The contractor functions as a *gatekeeper* between the third party and the purchaser. Gatekeeping also occurs when an industry partner transfers services to a government organization, which then passes the services to a government customer. The software factory primarily functions as a gatekeeper. The final brokerage role, the *itinerant*, arises when an industry partner acts between two government organizations. All itinerant brokerage relationships within the software factory network are managed through formal contract vehicles. The influence of brokers must be considered in conjunction with their organizational affiliation and the flow of resources through the network.

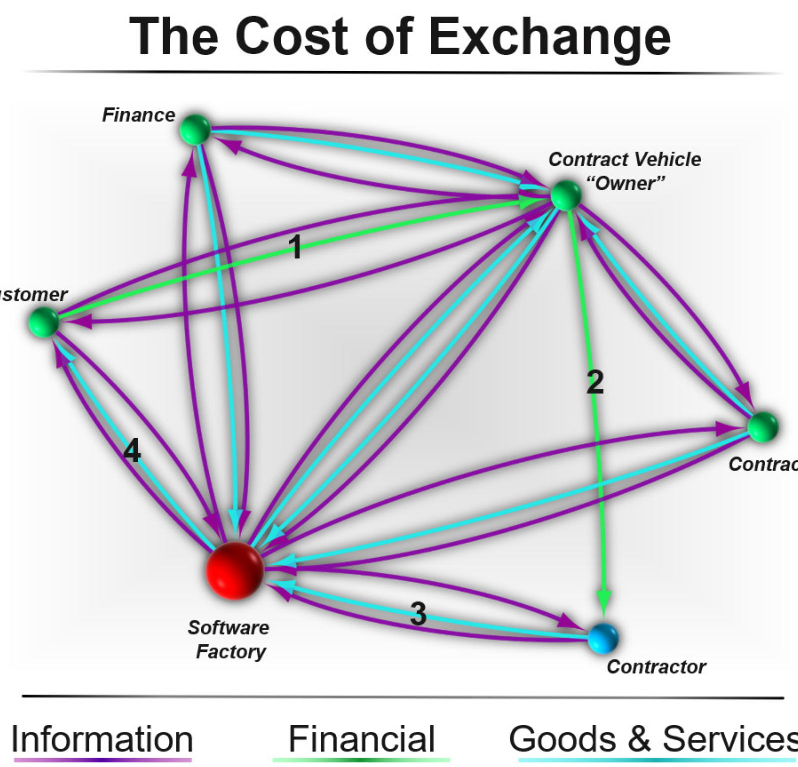
In situations where traditional hierarchical structures are not clearly defined, identifying the organizations that hold the most influence over a program can be challenging. However, ION-A can aid practitioners in this task by providing a visual representation of the program's interorganizational relationships. By analyzing these resulting models, researchers can assess centrality, identify resource flows, and determine broker roles. This information can then be used to pinpoint influential organizations. Next, the analysis will explore how identifying patterns of exchange can inform the big-picture perspective of a program and assist in decision-making.

Exchange Patterns

At this point in the ION-A process, significant organizations and their relationships within the program's network have been identified and assessed with the help of network-based measures such as multiplexity and centrality. In contrast, identifying exchange patterns demands a more refined analytical approach. Instead of relying on specific measures, it is important to identify exchange patterns needed to complete known interorganizational transactions. Additionally, since the relative importance of specific transactions is unique within each program, the program's mission statement, its organizational objectives, and its core functions should also be considered. The analysis in this paper concentrated on the transactions between the software factory and its customers due to their frequency and relative importance to the program's strategy.

Figure 7 illustrates the exchanges required to execute a typical transaction between a customer organization and the software factory. In addition to the primary exchanges, secondary exchanges are arising from support functions such as contracting, finance, and legal services associated with the execution of funds. Since the software factory does not maintain these functions organically, it engages external organizations' help. These exchanges, which must be coordinated by factory personnel, represent transaction costs, which are sometimes neglected using internal government analysis methodologies.

FIGURE 7. EXCHANGE FLOW AND TRANSACTION COSTS



Note. Four primary exchanges must occur to complete a transaction between the software factory and a customer: (1) the customer sends money to a third-party organization that maintains an existing contract vehicle; (2) money is sent to the contractor via the vehicle; (3) the contractor provides services to the software factory; and (4) the software factory provides services to the customer organization. In summary, the software factory orchestrates every step of the transaction through its social and economic connections.

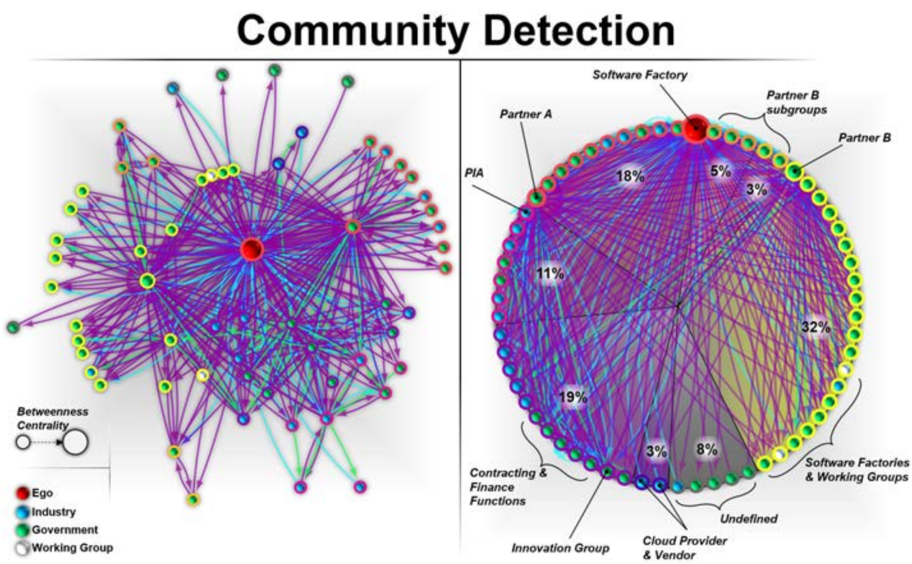
After analyzing the transactions of interest, network models should be assessed holistically to identify areas of activity that seem unusual or out of place. When the reasoning behind an exchange pattern is unknown, experienced members of the organization should be consulted and asked clarifying questions using the network model as a visual guide. Finally, an evaluation of exchange patterns should be conducted to determine if any can be simplified to reduce the overall cost of individual transactions. Step 3 of the ION-A process concludes with an assessment of the communities within the program's interorganizational network.

Examining exchange patterns can help identify dependencies on economic or social resources, enabling the development of proactive mitigation strategies in line with risk management best practices.

Communities of Interest

Identifying communities within the program's interorganizational network allows practitioners to comprehend and navigate the intricate relationships and interdependencies that exist between organizational subgroups. Community detection algorithms can quickly identify these communities. A hierarchical community detection algorithm (Pons & Latapy, 2005) was applied to the software factory network; seven distinct communities of interest were highlighted (Figure 8). The largest communities roughly aligned with the parent commands of the two partner organizations, activity associated with a local "innovation group," and a community of organizations associated with an industry partner acting under a Partnership Intermediary Agreement (PIA). The algorithm also highlighted three additional smaller communities: two of these communities can loosely be categorized as subgroups of Partner B; one highlights a gatekeeper brokerage pattern between an industry partner and a cloud vendor.

FIGURE 8. COMMUNITY DETECTION



Note. A random walk community detection algorithm was utilized to identify communities of interest within the composite software factory network. Community detection algorithms identify subgroups within a community by measuring connections between nodes. When applied to the software factory network, seven separate clusters were identified. While many clusters were easily attributable to known communities, others provided additional insight by highlighting previously unknown subgroups.

When applied to the software factory network, the community detection algorithm accurately identified known communities, indicating its validity as an assessment tool. Additionally, its identification of smaller subgroups within the software factory network provided an alternative perspective on subgroup dynamics. By identifying communities of interest early in the program life cycle, the PM can plan the organization's growth to align with community needs.

The analysis step of the ION-A process is now complete. This step utilized the network models created in Step 2 to identify influential organizations, organizational relationships, common exchange patterns, and communities of interest within a nontraditional program's interorganizational network. This information can provide the PM with a foundational understanding of the interorganizational dynamics of their program and can then be used to establish an informed perspective.

Step 4—Monitor and Review

The fourth step in the ION-A process involves ongoing monitoring and assessment of the interorganizational network. PMs should regularly update the network analysis to accommodate new contextual information, as networks are dynamic and subject to change over time. By frequently updating the network data, managers can obtain a measurable visualization of organizational evolution and growth.

This section demonstrates how practitioners can evaluate a program's interorganizational network to gain insights into organizational interactions and behaviors. Identifying influential organizations and relationships can inform stakeholder management plans and aid in prioritizing future interactions. Examining exchange patterns can help identify dependencies on economic or social resources, enabling the development of proactive mitigation strategies in line with risk management best practices. Community identification can offer insights into social dynamics and uncover previously unknown communities of interest.

In this specific case history, the results of the network analysis process (summarized in Table 2) were used to establish a shared internal understanding of the interorganizational relationships and behaviors of the program. The network graphs created during the analysis were also used to help communicate the intangible scope of software factory operations and program interdependencies to senior leaders outside the organization. Additionally, the software factory was able to use the analysis to identify enterprise-level, high-cost interorganizational processes and communicate how these costs could be reduced by increasing internal resources.

TABLE 2. THE ION-A PROCESS

Influential Organizations	Relational Assessment	Exchange Patterns	Community Assessment
Partner Organizations A & B, Contract Vehicle Owners, Financial Brokers, Cloud Contract Liaison, PIA Org, Innovation Group	Weakest Relations: Unidirectional information reporting, Brokered vendor relations Strongest Relations: Factory Partners, Factory—Platform Provider, Factory—Personnel Services Org	Customer—Factory Transaction: Requires 6 Orgs & minimum 4 economic exchanges; 3 industry partners funded through multiple sources; financial convergence through contract vehicle owners	Four dominant communities: Partner A, Partner B, Innovation Group, & PIA; 3 subgroups: 2 Partner B & Cloud Vendor

Strategic Insights:

- Industry partners are funded through multiple sources/customers with competing expectations, interests and requirements: this complicates program-level cost, schedule, and performance metrics/assessments. Alternative, customer-centric metrics should be developed.
- The software factory primarily acts in the "gatekeeper" broker role. Industry partner services are rendered to customers through the software factory: this is an unstated benefit/service of the software factory structure. Consider emphasizing this role when engaging potential customers.
- The software factory relies on many organizations within its network for resources (financial, services, and information): this prevents power centralization and provides increased autonomy to the factory at a cost to organizational stability.
- Accounting data are fragmented and dispersed across five organizations and two MAJCOMs: this makes it difficult to communicate total program cost.
- The software factory relies heavily on its social network to operate: this places a strain on key members of the organization (Cook, 1977) and limits organizational mobility (Blau, 2017). Consider implementing a customer liaison/outreach role to manage social exchanges.
- The social costs required to execute economic exchange are high: the factory should identify ways to reduce the cost of customer-factory transactions. Transaction steps are currently "tribal" knowledge and they should be formally documented to combat knowledge attrition.
- The relationships between cloud providers are weak and rely on third-party industry partners: this introduces a risk to a critical resource.
- Partner communities dominate the interorganizational network: the software factory should strengthen relationships with additional communities to reduce partner dependencies.

Note. This process provides practitioners with a method to assess the social and economic relationships of their programs. This case history assessed an existing DAF software factory in four key areas: organizational influence, relationship strength, exchange patterns, and communities of interest. Strategic insights, organizational risks, and potential opportunities tailored towards the specific needs of this nontraditional software factory organization are derived from the ION-A process.

MAJCOMs = major commands; PIA = Partnership Intermediary Agreement.

In summary, the ION-A process provides acquisition practitioners with a strategic perspective on the social and economic relationships within their programs. This section illustrated this point by presenting a case history of a nontraditional software program showcasing the practical benefits of network analysis. Table 2 presents a summary of the most relevant outputs and strategic insights gained from the ION-A process.

Limitations and Future Work

The aim of this case study was to demonstrate a practical network analysis process capable of capturing and understanding the social and economic relationships of nontraditional software programs. This process, termed ION-A, streamlines the network analysis process by predefining the scope of the analysis, the variables of interest, and the analysis techniques employed, reducing the initial research and planning requirements for PMs. While this predefinition makes network analysis more accessible, it also limits the applicability of ION-A to cases similar to the demonstrated case. Furthermore, the field of network analysis provides countless techniques, tools, and analysis methods available to researchers, which have not been discussed. For instance, alternative measures of relationship strength (e.g., dollars exchanged, frequency of exchanges) and organizational influence (e.g., eigenvalue centrality, closeness) could be employed. These and many other techniques present an exciting opportunity for future research as they may reveal additional insights into the organizational dynamics of programs.

Conclusions drawn regarding the specific software factory analyzed within this case study also face limitations. First, the results generated from this network analysis are highly temporal. Organizations are constantly evolving, and this analysis represents a single snapshot in time. Second, the results from this network analysis cannot be used to assess the validity or effectiveness of the nontraditional organizational structures employed by the DoD's software factories. Although this study provides insight into the relationships of the featured organization, it only captures a single data point in the context of the broader software ecosystem. Future studies could utilize the framework established within this study to capture and analyze the ego networks of multiple organizations within the ecosystem. This would allow for a more in-depth statistical analysis of the programs' interorganizational networks.

Lastly, this study is constrained by data availability. Data on software factory performance are limited. As a result, the data employed in this study were gathered through interviews with members of the software factory of interest, and the members' bias can be assumed based on their perspectives, organizational goals, and opinions. The analyzed organization is in its infancy; inevitably, it is in the interviewees' best interest to present a positive view of their organization. Although this study implemented a structured approach to mitigate this effect, it cannot be eliminated entirely. Due to these limitations, the analysis process presented in this case study can only be used to identify the existence of organizational characteristics and behaviors for the organization under examination.

Future research could explore the integration of additional network analysis techniques and measures of relationship strength (e.g., dollars exchanged, frequency of exchanges) or organizational influence (e.g., eigenvalue centrality, closeness) to further refine the ION-A methodology. Additionally, researchers could investigate the applicability of ION-A to a broader range of nontraditional defense programs like those operating under the software acquisition pathway or compare the effectiveness of ION-A to other existing network analysis approaches. Through ongoing research and development, the ION-A methodology can continue to evolve and provide program managers with increasingly effective tools for assessing and understanding the social and economic connectivity of their programs.

Conclusions

This article began by highlighting that existing guidance for acquisition programs is tailored toward organizations with traditional hierarchical structures; thus, it may not be sufficient for assessing nontraditional programs. This led to the formulation of a research question designed to address this gap in understanding: *How can program managers assess the interorganizational structures of nontraditional software organizations?*

To answer the research question, we developed and applied a process called ION-A and demonstrated its effectiveness using the case history method on a nontraditional DAF software factory. The ION-A process, which employs the network analysis principles of multiplexity and egocentricity to capture the economic and social relationships of a single program of interest, has been simplified for practicality yet still provides a technically sound foundation for practitioners to analyze and understand the organizational structures of their programs.

The ION-A process describes how practitioners can collect and organize network-centric program data that can be used to model the social and economic relationships of their programs. It also describes data collection techniques and identifies open-source software programs that can be used to create an interorganizational network from the collected data. The ION-A process progresses by guiding practitioners through an analysis of four focus areas of interorganizational networks using a framework of contextual assessments. Table 3 includes a summary of this framework, which addresses these four focus areas, provides initial assessment questions, and identifies a collection of relevant analysis techniques and network models that can be used in the analysis.

TABLE 3. THE ION-A ASSESSMENT

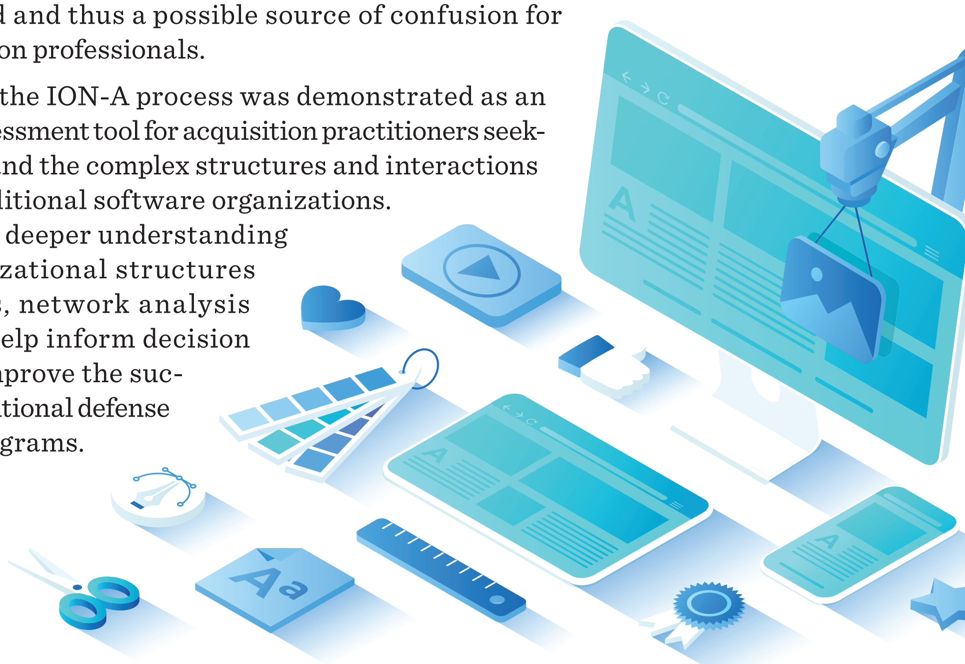
Area of Interest	Contextual Assessment	Network Indicators
Relationship	***Identify the weakest and strongest relationships within the organization's network.*** a. Are the social and economic costs of these relationships in alignment with the goals of the organization? b. Can strategic relationships be strengthened by establishing additional types of exchange relations? Should they? c. Are any interorganizational relationships stronger or weaker than anticipated? Why?	Composite Network (Figure 4A), Multiplexity & Tie Strength (Figure 5)
Organizational Influence	***Identify the most influential organizations within the network. Consider both the social and economic environments.*** a. Which organizations are centrally located? Why? b. Which organizations are acting in broker roles? What is their affiliation? c. Which organizations control access to resources? Information? Is this an acceptable risk? d. Does the flow of resources converge at any specific organization? e. What happens if these organizations exit the network?	Economic, Social, and Composite Networks (Figure 4A-D), Centrality Measures, Network Positioning. Resource Flows. Broker Roles (Figure 6)
Exchange Patterns	***Identify common patterns of exchange.*** a. How many exchanges must occur to complete a transaction? Should this be reduced? b. Are critical patterns of exchange formally documented? c. Are there any patterns of exchange that could be standardized? Simplified? d. Are economic exchanges supported by social exchanges? If not, why?	Economic, social, and composite networks (Figures 4A-D), Exchange patterns (Figure 7), Resource flows, Directionality
Communities of Interest	***Identify clusters of organizations or communities of interest.*** a. Is it possible to explain the existence of each community? b. Are there any subgroups that were previously unknown? c. Do any organizations seem misplaced? Why? d. Are communities clustered around specific organizations? What are they?	Composite Network (Figure 4A), Community Detection (Figure 8)

Note. This process guides practitioners through an assessment of the interorganizational network of their programs. The analysis framework used in Step 3 of ION-A focuses on four primary areas of interest in order to provide a foundational understanding of program dynamics. Questions designed to guide the assessment are provided along with relevant network-based indicators.

In addition to developing and demonstrating a new assessment approach, this case history also provided a network-centric look into the underlying mechanisms driving nontraditional software factories. While these insights hold value, performing a network analysis can be time consuming. Nonetheless, advancements in network management continue to increase their worth, resulting in practical applications for industry practitioners to gain fresh insights into organizational behaviors (Bodan et al., 2016; Cross & Gray, 2021). Open-source graphing applications, which aided the analysis in this case history, also continue to evolve and become more accessible. As a result, practitioners' ability to apply network analysis techniques, such as ION-A, to gain insights into their organizations will keep growing. Cultivating and managing interorganizational partnerships and stakeholder relationships is crucial for any program and network assessment techniques like those described in this article, which enable practitioners to better understand these relationships early in the program life cycle.

This article contributes to both the Department of Defense and academia by demonstrating a structured approach to organizational analysis while also providing an in-depth look into an emergent acquisition organization, the software factory. This case history also provided insight into the structure and relationships of an organization prior to a formal entry into the acquisition system. Identifying alternative analysis methods for such organizations is important since this early period is largely undocumented and thus a possible source of confusion for many acquisition professionals.

In conclusion, the ION-A process was demonstrated as an alternative assessment tool for acquisition practitioners seeking to understand the complex structures and interactions within nontraditional software organizations. By providing a deeper understanding of interorganizational structures and behaviors, network analysis methods can help inform decision making and improve the success of nontraditional defense acquisition programs.



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Endnotes

[1] Multiplex, Egocentric Network Analysis: A multiplex network displays multiple types of relationships or ties between organizations. Egocentric networks focus on a specific organization of interest, defined as the ego (Perry et al., 2018). This differs from a sociocentric analysis approach, which seeks to derive insights into the whole network. Multiplexity is discussed in depth in the analysis section of this article.

[2] The utilization of the exchange as a way to measure organizational relations was initially proposed as a method for studying interorganizational behavior and relations in the early 60s by Levine and White (1961). Since its initial definition, the exchange has been broadly employed by researchers to measure both social and economic transactions between both individuals and organizations (Wasserman & Faust, 1994).

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FRUSTRATED WITH OBSOLESCENCE— TRY CHANGING YOUR MENTAL MODEL

Matthew D. Chellin and Erika E. Miller

This article explores mental models on obsolescence management to assist with mitigating obsolescence for Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance, and Reconnaissance (C5ISR) systems. A systems-thinking methodology was used to develop these mental models, which were validated through interviews with 10 participants. The participants were U.S. Army acquisition practitioners at Aberdeen Proving Ground, Maryland. This research complements the tools and training for mitigating obsolescence by deepening an organization's understanding of the relationships among systems and the mental models that influence obsolescence management. These mental models are foundational to the interaction relationships of the system of interest (Diminishing Manufacturing Sources and Material Shortages, or DMSMS Management System) within the context of engineered systems. This is enabled by supporting systems such as the supply chain, configuration management, and the budget. Furthermore, this research presents a novel model of the systems within the obsolescence management system. Based on the relationships in the causal loop diagrams and application of a risk-based proactive obsolescence management mental model, one can predict a higher or lower likelihood of successfully mitigating a C5ISR system's obsolescence.

DOI: *https://doi.org/10.22594/dau.23-903.30.03*
Keywords: *DMSMS Management System, models, obsolescence, supply chain, systems thinking*

Image designed by Ken Salter

Obsolescence in Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) systems is a challenge that often frustrates practitioners. Obsolescence challenges require solutions many times over the life cycle of a system due to the constant changes in technology. The motivation for writing this article is to increase the likelihood of successful obsolescence mitigation that, for purposes of this article, is defined as finding solutions to negate or significantly lessen the effect of C5ISR functionally outdated system components. This can be accomplished by using mental models to understand and change system behaviors that are the underpinnings of obsolescence management.

Changing an organization's mental model will complement training provided to acquisition practitioners that routinely mitigates obsolescence challenges from short- to long-term solutions. These gains are furthered by using tools to adjust the mental model of an organization and its teams to achieve obsolescence mitigation within the underlying system that supports the activities of obsolescence management (i.e., in a system of interest [SOI], a system context, and in enabling systems). This article discusses the mental models that guide an organization's behavior toward mitigating obsolescence for C5ISR systems. The goal is to transform the obsolescence management practices of an organization and its teams by using a systems-thinking approach. Doing so can produce effective and efficient obsolescence mitigation aimed at achieving systemic change by adopting a risk-based proactive obsolescence management (RPOM) mental model.

This research focuses on the system modeling of obsolescence management using systems-thinking tools to guide future changes to the fundamentals of DoD's Diminishing Manufacturing Sources and Material Shortages (DMSMS) Management System. This system modeling will enable the defense acquisition community to achieve shorter schedules, lower costs, and higher availability of system components for the sustainment of C5ISR systems. The modeling in this article (Figure 1) shows the complexity of the obsolescence management challenge and offers a risk-based proactive obsolescence model that improves the odds of mitigating obsolescence challenges through proactive obsolescence management rather than reactive obsolescence management.

FIGURE 1. RELATIONSHIP BETWEEN MITIGATION RISK AND OBSOLESCENCE MANAGEMENT MENTAL MODELS

Many C5ISR practitioners are well trained in the methods and tools to mitigate obsolescence (Chellin & Miller, 2023). This research aims to assist with filling a systemic gap to support gaining governance over the obsolescence challenges that are routinely encountered by C5ISR systems. Furthermore, this area warrants additional research to develop tools that are more robust to assist acquisition practitioners who are assigned to mitigate the obsolescence challenges for C5ISR systems. The training and tools are powerful enablers for managing obsolescence. To that end, this article goes systemically deeper; its main focus is on characterizing the mental models of obsolescence management and providing a framework to achieve successful RPOM and mitigation for C5ISR systems. This research article uses the tools of systems thinking to effect change with mental models that are applicable to an individual, a team, and an organization, changing fundamental system adjustments from a reactive obsolescence management approach to a proactive risk-based obsolescence management approach. This will allow a broad spectrum of successful mitigation strategies across a multitude of systems. Training and tools are available to assist practitioners with the mitigation of obsolescence challenges. However, a gap in the current research challenges practitioners to examine systemic behaviors in the acquisition community that mitigate obsolescence.

Based on the experiences of C5ISR practitioners, obsolescence management as a system tends to default as a reactionary loop. This loop leads to more of the same fundamental challenge—a lack of availability of system components when needed. This challenge is often discussed in the prevailing DMSMS literature. The challenge of sustaining long-lived C5ISR systems does not immediately appear to be a complex problem; however, it is a deceptively complex problem in which a practitioner does not recognize an obsolescence challenge until it becomes an immediate issue. This article is intended to set forth and help incorporate an RPOM model that will enable organizations to better understand and manage their obsolescence risks.

> **The challenge of sustaining long-lived C5ISR systems does not immediately appear to be a complex problem; however, it is a deceptively complex problem in which a practitioner does not recognize an obsolescence challenge until it becomes an immediate issue.**

Background

The literature supports addressing complex problems with a systems-thinking approach, thereby increasing the probability of developing a successful solution. Finding a successful solution to a complex problem can be very difficult because any changes are highly interconnected; it takes time to tell if the changes are an improvement, produce no noticeable change, or make the problem worse. Rittel and Webber (1973) described types of problems as (a) tame problems, which are relatively simple to solve, and (b) wicked problems or dilemmas, which are very complex and difficult to solve. The wicked problems require a more robust toolset to solve; the challenge of managing obsolescence that affects C5ISR systems is one such challenge. A team as well as an organization's understanding of their challenges and the path to successful mitigation strategies are guided by mental models. Mental models are based on formulated knowledge gathered from one's own interactions and perceived view of the experiences of others; this can be used to depict and predict interactions within one's own surroundings (Cannon-Bowers et al., 1993; Johnson-Laird, 1983; Rouse & Morris, 1986). The literature does advocate for proactive obsolescence management over reactive obsolescence management. Sandborn (2004) described the sustainment advantages offered by proactive obsolescence management. Additionally, key areas of the obsolescence management challenge were discussed in Sandborn (2007).

The beginnings of systems thinking can be traced back to Professor Jay Forrester, who founded systems dynamics in 1956 at MIT (Forrester, 1995). The work of Donella "Dana" Meadows defined a system as elements, interconnections, and a function or purpose. She provided a sports example to illustrate thinking in systems to open one's mind to what a system truly is, and this example also shows its applicability to more than engineered systems. In football, for example, elements include the coach, players, ball, and field; interconnections include communications between the players, rules, and coach's strategy; and the purpose is to win. The higher leverage areas to change a system are in the purpose and the interconnections; change the purpose from winning to tying or losing and the entire game has significantly changed (Meadows, 2008). She also introduced a very important stock element for understanding systems and defined a stock as "the elements of the system that you can see, feel, count, or measure at any given time" (p. 17). Illustrating similar points, the work of Russ Ackoff (2010) used many examples in areas such as education, management, and government, focusing on systems thinking and emphasizing the interactions, feedback, and system as a whole. These stocks were further used in modeling work by Stroh (2015), showing the construction of a causal loop diagram and explaining the relationships and terminology, where an (S) or (+) indicates more of the same in a positive direction, an (O) or (-) indicates a response in the opposite direction, and double lines indicate a delay in the process.

The systems-thinking and systems-dynamic approach to solve complex problems was popularized by Senge (2006), who highlighted the techniques that increase an organization's chance of solving complex problems that do not have a straightforward solution. The analysis by Kenett et al. (2020) examined the tools to address complexity in the context of applied systems thinking, systems engineering, software cybernetics, and risk management. Kasser (2015a) showed that deep systems-thinking fundamentals

support the value of thinking in a way where the whole is more than the parts. Jackson (2016) provided a comprehensive guide through the areas of systems thinking (e.g., the systems language, applied system thinking, creativity and systems, hard systems, soft systems methodology, systems dynamics, organizational cybernetics, and complexity theory). Similarly, from a business point of view, Sterman (2000) provided a comprehensive guide to systems thinking. Some of the areas Sterman examined were learning about complex systems, system dynamics, modeling, structure and behavior of dynamic systems, and tools for systems thinking. The work of Kasser (2015b) discussed the advantages of using a holistic-thinking approach over the traditional technology readiness level (TRL) as a more useful conceptual tool to understand the technology life cycle from concept to obsolescence. Although his work discussed systems thinking, the application of the tools to address the complex change of obsolescence management is outside the scope of this article.

Previous literature suggested a gap with respect to applying the tools of systems thinking to the complex problem of obsolescence management. This is a deceptively complex problem because, at the surface, it is difficult to identify the causes and interconnections of the challenges among the SOI, the enabling systems, and the context systems. Moreover, this research complements other research on obsolescence management by providing systems-thinking models to guide teams and organizations in their pursuit of transformation from reactive obsolescence management to RPOM.

The policies outlined in SD-26, *DMSMS Contract Language Guidebook* (DoD, 2019); DoDI 4245.15, *Diminishing Manufacturing Sources and Material Shortages* (DoD, 2020); and SD-22, *Diminishing Manufacturing Sources and Material Shortages: A Guidebook of Best Practices for Implementing a Robust DMSMS Management Program* (DoD, 2022) could be complemented by the systems-thinking approaches presented in this article. Overall, previous literature recognizes the complex challenge that is obsolescence management; to that end, this research is intended to complement the existing literature. Moreover, this article fills a gap in the deeper analysis needed to address obsolescence management with systems-thinking tools.

Problem Statement

The importance of proactive obsolescence management rather than reactive obsolescence management is recognized among acquisition practitioners. However, many systems support reactive obsolescence management by applying expertise to immediate obsolescence challenges, but that slows an organization and its many teams from being able to proactively plan the long-term obsolescence mitigation future.

Software tools are currently available to address patterns and structure that assist with transitioning from reactive to proactive obsolescence management. However, understanding this deeper challenge from a systems-thinking perspective is essential. Using the mental models, this perspective addresses the deep structural change needed to transform an entire organization from reactive obsolescence management to RPOM. A better understanding of the complexity of the obsolescence challenge would lead to more meaningful and longer lasting mitigation strategies. The challenge of successfully managing the obsolescence management of systems is complex. The research to date supports proactive obsolescence mitigation strategies. However, conducting more systems-thinking research may increase the understanding of the complex *behaviors* that contribute to both reactive obsolescence management and RPOM. It is essential to understand the broader and deeper systemic behavior that acts as a barrier to proactive obsolescence management of C5ISR systems, as well as the mental model transformation required for teams and organizations to achieve RPOM.

Research Questions

1. What are the main relationships that predict obsolescence management outcomes?
2. What are the systems that govern obsolescence management behavior?
3. What are the underlying mental models that guide an acquisition practitioner's approach to obsolescence management?

Methodology

A predominantly qualitative research design with a phenomenological research methodology was used to gain insights about systems relationships for obsolescence management. Experienced practitioners were shown elements and interconnections between parameters that impact the availability of components for C5ISR systems. The figures shown in this article to represent the elements and interconnections were originally developed from input collected in Chellin and Miller (2023). Based on that initial research, we developed an iceberg model and causal loop diagrams for this article, which are provided in the Analysis and Results section that follows. These diagrams were presented to participants to validate or suggest changes. The participants are C5ISR practitioners, including engineers and logisticians who are routinely challenged with finding solutions to obsolescence challenges. The experiences of the C5ISR practitioners come from numerous near-obsolete and obsolete line replaceable units and system component-level challenges. The participants were 10 government employees: five engineers and five logisticians from the U.S. Army located at Aberdeen Proving Ground, Maryland. At the time of the study, the participants all supported C5ISR systems, specifically in the operations and support phase of the system life cycle.

Participants were asked several open-ended questions and provided feedback on the relationships to validate the models. The interview also included structured questions that asked the participants to rank their level

"A better understanding of the complexity of the obsolescence challenge would lead to more meaningful and longer lasting mitigation strategies.

of agreement with the modeled relationships for both reactive and risk-based proactive obsolescence management. Level of agreement was rated on a 5-point Likert scale *(strongly disagree, disagree, neither agree nor disagree, agree, strongly agree)*. Table 1 lists the interview questions. The interviews lasted approximately 30 to 45 minutes. Each interview was conducted separately with each participant. (Note: This study had Institutional Review Board approval from Colorado State University.)

TABLE 1. INTERVIEW QUESTIONS FOR ALL 10 PARTICIPANTS

Interview Questions
1. What is your area of expertise?
2. How many years of experience do you have?
3. What is your gender?
4. How much do you agree or disagree with the following reactive obsolescence management relationships? [See Figure 3.] Strongly Disagree Disagree Neither Agree nor Disagree Agree Strongly Agree
5. What are the areas that you would recommend changing?
6. How should these areas change?
7. How much do you agree or disagree with the following risk-based proactive obsolescence management relationships? [See Figure 4.] Strongly Disagree Disagree Neither Agree nor Disagree Agree Strongly Agree
8. What are the areas that you would recommend changing?
9. How should these areas change?
10. What are your thoughts on the mental models that guide obsolescence management? [See Figure 2 and Table 3.]

Analysis and Results

Pattern of Behavior

The behavior at various tiers within the supply chain is used to forecast procurement of obsolete or near-obsolete components needed for the estimated life of the system. This behavior intuitively makes sense; however, the results are often counterintuitive because the forecasts often predict far into the future, which diminishes the accuracy of the estimate. For a variety of reasons, the life of an obsolete or near-obsolete system is typically extended (e.g., when the replacement system is not ready or was abandoned due to technical maturity challenges or budgetary issues).

Systemic Identification

The next part of this article explores the obsolescence challenge within the framework of the SOI, a system context, and enabling systems. In this article, the SOI is the DMSMS Management System, the system context is the Engineered Systems, and the three enabling systems are Supply Chain, Configuration Management, and Budget System.

Rationale for Complexity

Table 2 applies the foregoing system-defining areas to create a baseline understanding to support the subsequent development of the mental models.

TABLE 2. PURPOSE, ELEMENTS, AND INTERCONNECTS OF SYSTEMS

System	Elements	Interconnects	Purpose
DMSMS Management System (system of interest)	Engineers, logisticians, financial analysts, management, databases, plans, reports, and contracts	Team communication, policy, funding rules, and strategy	Maintain availability of components to support the procurement and repair of systems
Engineered Systems (system context)	Parts, components, subsystems, systems, system of systems	Team communication, engineering principles, engineering coordination with other teams	Perform in accordance with system requirements
Supply Chain (enabling systems)	Parts, components, subsystems, systems, system of systems	Communication between suppliers and customers at multiple points of the supply chain.	The flow of materials from suppliers to customers
Configuration Management (enabling systems)	Configuration management tool, technical data, engineers, and logisticians	Team communication (internal & external), policy, and strategy	Approves engineered system changes without breaking any functionality for its users
Budget System (enabling systems)	Financial database, financial analysts, management, and stakeholders	Team communication (internal & external), funding rules, policy, and strategy	Efficiently spends resources and balances the resource needs of many systems

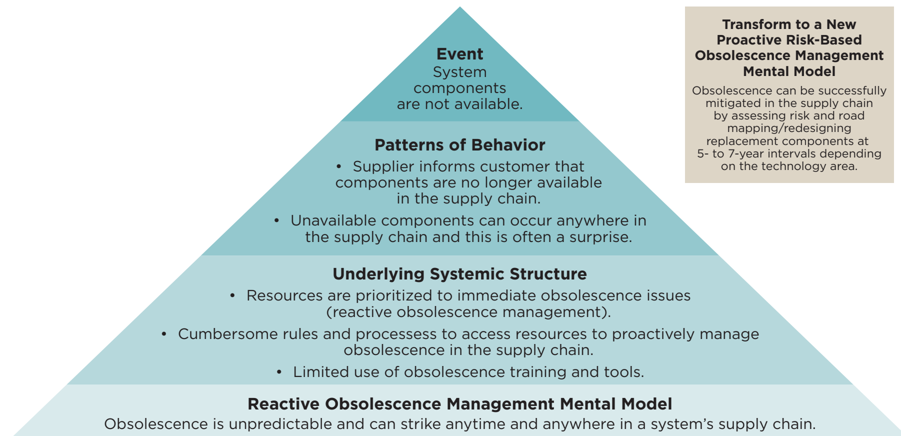
Based on the experiences of the C5ISR practitioners, obtaining components for long-lived C5ISR systems is a historically complex challenge that becomes more complex and challenging as the rate of technical change accelerates. This challenge is more commonly known as DMSMS. This is a complex problem because of the interactions between the SOI, system context, and three enabling systems. Also, these individual systems have misaligned or different purposes from the overall system goal of mitigating obsolescence. As such, the dominant, current, mental model is reactive obsolescence management.

The modeling discussed in this article shows the obsolescence mitigation advantage for a C5ISR system by transforming the obsolescence management mental model to RPOM. This will help an organization to adapt an obsolescence management approach that successfully adjusts to the systemic complexity associated with the interconnections and purposes among the many stakeholders. The different or misaligned purposes are identifiable as reactive obsolescence-mitigation behavior because the interactions of the stakeholders are focused on immediate obsolescence fixes, while seemingly unaware of the trade-off for predictable, long-term, obsolescence-mitigation solutions. This intense focus hides the true relationships from stakeholders in that they are unable to find the true purpose of successfully mitigating obsolescence, which is found through RPOM mitigation behaviors. Furthermore, the mental model must change to achieve sustainable obsolescence-mitigation outcomes. The modeling and analysis in this article propose a new mental model of RPOM that allows an organization to mitigate obsolescence challenges efficiently and effectively for C5ISR systems.

Mental Model Transformation

The following analysis is based on participant feedback and validation. The tools of systems thinking are employed to understand and change the mental models, which are guided by the practitioner experiences with the SOI , the context systems, and the enabling systems. Figure 2 utilizes an iceberg model to provide an overview of the complex structure of the DMSMS Management System operating under a reactive obsolescence management mental model. Using an iceberg model, a practitioner, a team, and an organization can more easily and quickly obtain information from the top of the model (i.e., the event). However, the deeper one goes into an iceberg model, the greater the leverage to effect lasting and meaningful change with the affected systems (Stroh, 2015). The greater leverage areas include patterns of behavior followed by the underlying systemic structure with the greatest leverage area at the bottom (Stroh, 2015).

FIGURE 2. REACTIVE OBSOLESCENCE MANAGEMENT ICEBERG MODEL AND TRANSFORMATION



Proactively mitigating all the parts and components of a system is not cost-effective. Therefore, based on this consideration, the mental model is updated to reflect RPOM. After a team or an organization's transition from a reactive obsolescence management mental model to a proactive obsolescence management mental model, the reality of a resource-constrained environment will still be present. This is why proactive obsolescence management needs to be guided by risk in the mental model, thereby supporting the early assessment of where to focus proactive obsolescence-management efforts based on risk. The C5ISR participants had stressed risk management as a key aspect of supporting proactive obsolescence mitigation. The research participants highlighted the components that often change due to frequent technology advances, have fewer suppliers as high-risk, and require focused expertise to mitigate obsolescence. Proactive obsolescence management can also benefit lower risk components that have a predictable useful life with planned replacements. However, the least risky components and parts that rarely change (e.g., assembly hardware such as nuts, bolts, etc.) do not merit any obsolescence risk-management mitigation activities.

Table 3 shows the evolution of the mental model incorporating double-looped learning. The mental model's changes require consideration of the behavior of the SOI, system context, and enabling systems.

TABLE 3. OBSOLESCENCE MANAGEMENT MENTAL MODEL EVOLUTION

Iceberg Model Elements	Model: Reactive Obsolescence Management	Model: Proactive Obsolescence Management	Model: Risk-Based Proactive Obsolescence Management
Events: What is happening?	Can no longer order the needed component(s) for the system(s)	Can no longer order the needed component(s) for the system(s)	Can no longer order the needed component(s) for the system(s)
Patterns of Behavior: Trends over time	The team does not worry about obsolescence until it is an immediate problem	The team plans as early as possible to address obsolescence	The team plans as early as possible to address obsolescence considering risk
Systems Structure: Structural forces contributing to these	Funding is not available until an immediate impact can be characterized, lack of technical data/foresight, design team sees it as someone else's problem	Not enough funding to mitigate every component, characterize the obsolescence early, design team plans/partitioned the systems for component replacement, plans in the interface control document	Early funding of high-/medium-risk components, characterize the obsolescence early, the design team redesign's alternate components for early high-/medium-risk components
Mental Models: Assumptions, beliefs that shape the system	Manage obsolescence on an as needed basis late in a system's life cycle	Manage obsolescence as early as possible in a system's life cycle	Manage obsolescence as early as possible based on risk in a system's life cycle

The final evolution from a proactive obsolescence management system to an RPOM system is essential to make the most effective and efficient use of the resources and expertise of the teams assigned to mitigate the obsolescence challenges.

The causal loop diagrams in Figures 3 and 4 show the modeling that was validated as executable representations by the research participants—acquisition practitioners who are routinely assigned the task of finding

> **After a team or an organization's transition from a reactive obsolescence management mental model to a proactive obsolescence management mental model, the reality of a resource-constrained environment will still be present.**

solutions to mitigate the challenges of C5ISR systems. The first causal loop diagram (Figure 3) models reactive obsolescence management, and the second causal loop diagram (Figure 4) models RPOM.

FIGURE 3. REACTIVE OBSOLESCENCE MANAGEMENT CAUSAL LOOP DIAGRAM

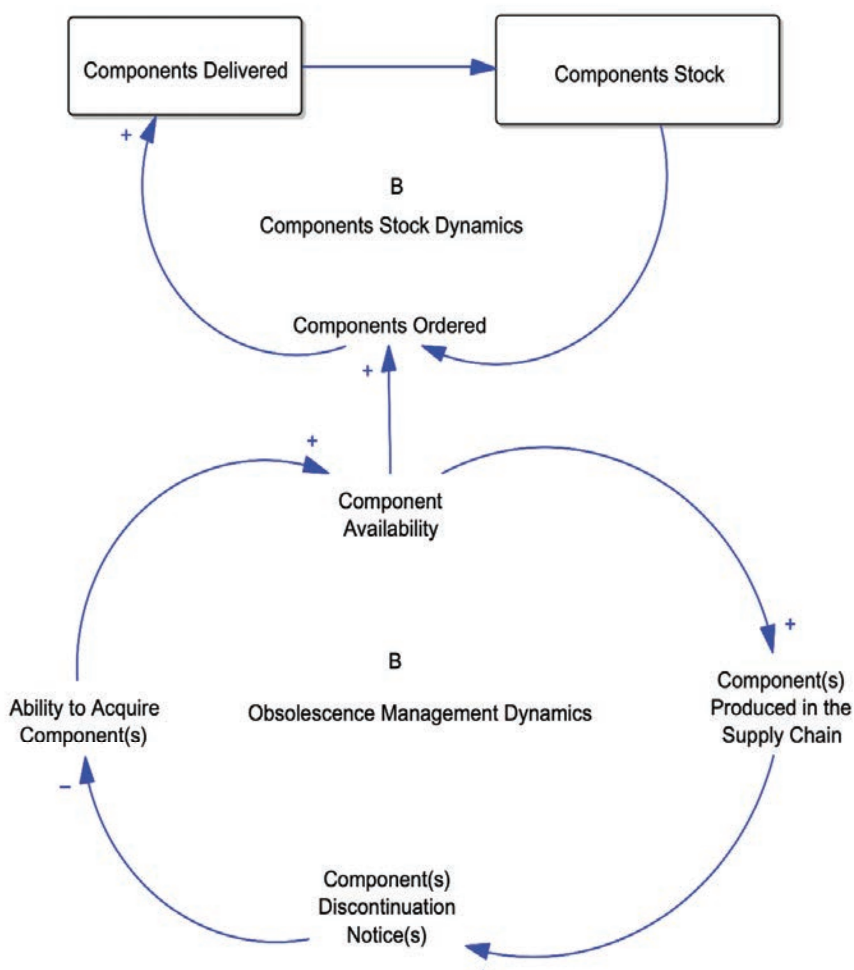
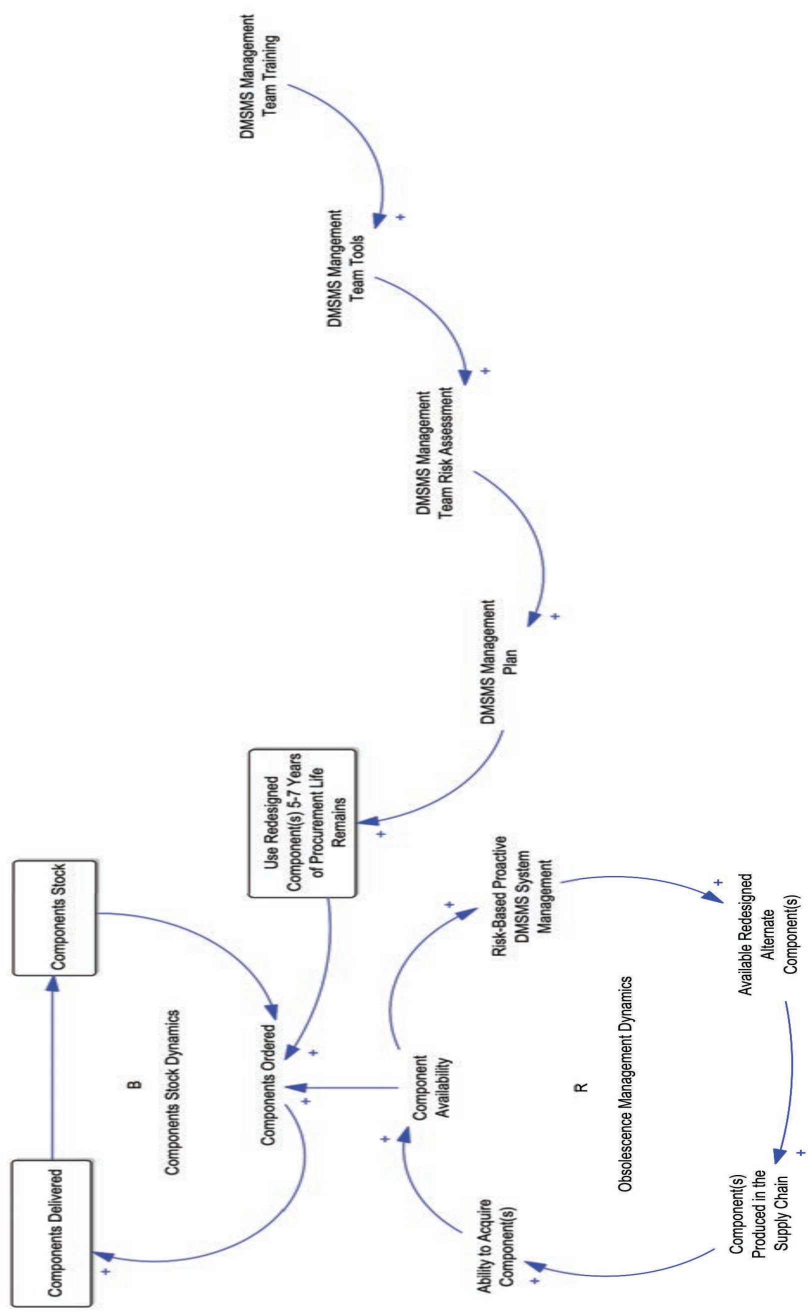


FIGURE 4. RISK-BASED PROACTIVE OBSOLESCENCE MANAGEMENT CAUSAL LOOP DIAGRAM



The causal loop diagram in Figure 2 depicts two balancing loops. The top loop shows the flow of components used within C5ISR systems. The bottom loop depicts the relationship of decreasing availability of components based on obsolescence. At this point, the options to mitigate obsolescence are limited and require significant effort to solve immediate challenges, which drives higher costs, longer schedules, lower availability, and the risk of nonavailability of replacement components. The research participants validated the reactive obsolescence management causal loop diagram as an executable representation: Six research participants strongly agreed with the model, four research participants agreed with the model, and no one disagreed with the model.

Figure 4 is the RPOM causal loop diagram. The research participants validated this diagram as an executable representation: Seven research participants strongly agreed with the model, three research participants agreed with the model, and no one disagreed with the model.

This causal loop diagram models the methods for a team to assess the component redesign risk 5 to 7 years in advance. The top balancing loop, as in the previous model, captures the flow of components that are used within C5ISR systems. However, in this model, the team and the organization are not limited to a shortsighted solution to address an immediate need. Moreover, the bottom loop is a reinforcing loop that supports the continuous flow of alternate components that can be redesigned with lower costs, optimal schedules, and higher availability.

Discussion and Conclusions

The system's behavior changes because of the alteration in the mental model from reactive obsolescence management to RPOM. All of the participants in this study agree or strongly agree that changing to an RPOM model better supports positive obsolescence-mitigation outcomes. Based on the results of this research, we provide the following insights toward promoting RPOM:

- SOI–DMSMS Management System: Include RPOM to significantly reduce the risk of encountering any significant DMSMS challenges.
- System Context–Engineered Systems: Plan and execute replacement component development or identification 5 to 7 years ahead of an obsolescence issue to support the procurement and repair of C5ISR systems.
- Enabling System–Supply Chain: Using an RPOM mental model supports advance planning, which reinforces better supply availability

across an engineered system's supply chain. This leads to a heathier ecosystem of supportability for an engineered system.

- Enabling System–Configuration Management: The RPOM mental model reinforces planning of the redesigned components within the systems configuration well in advance of the risk of surprise or shortsighted design changes, introducing a nonoptimal number of configurations or suboptimal configurations.
- Enabling System–Budget System: Funding activities to obtain alternate components for medium- to high-risk components 5 to 7 years ahead of an immediate obsolescence issue will avoid shock to budget systems, as well as cost increases resulting from additional efforts of the government and our industry partners.

The research questions are answered by the following research findings. Research questions 1 and 2 are answered by the SOI, the system context, and the enabling systems, in combination with the causal loop diagrams depicting the systems that govern obsolescence. This is predictive of the obsolescence management outcomes (i.e., reactive versus proactive obsolescence management). Research question 3 is answered by recognizing and understanding the reactive obsolescence management mental model, as well as the RPOM model, which is key to guiding an approach that will result in more proactive obsolescence-management outcomes.

Future research based on this study could repeat our modeling of obsolescence management by using systems-thinking methods with other military branches, as well as replicate this study with a larger sample size. Likewise, this study could also be expanded to other areas by using commercial systems that are not related to the military. Another area that could benefit from more research is tools to assist practitioners with assessing obsolescence (e.g., obsolescence risk analysis software to help the team assess the obsolescence risk for each component of a C5ISR system). Additionally, a

Based on the relationships in the causal loop diagrams, applying an RPOM mental model is a predictor of successful obsolescence mitigation because stock levels are replenished years in advance to create a sufficient buffer to protect from a component-level nonavailability event.

perception predominates among some research participants that excessive delays are inherent to obsolescence management system(s); however, it remains difficult to pinpoint where and how many delays are systemic within the systems that support obsolescence management. Therefore, another study focusing on delays by following the activities of samples through the process could inform future process mitigation solutions.

U.S. Army acquisition practitioners located at Aberdeen Proving Ground, Maryland, validated the mental models that guide both reactive obsolescence management and RPOM. Mental models are formed from the interaction relationships between the SOI, system context, and three enabling systems. Based on the relationships in the causal loop diagrams, applying an RPOM mental model is a predictor of successful obsolescence mitigation because stock levels are replenished years in advance to create a sufficient buffer to protect from a component-level nonavailability event.

A limitation of this research is that the model was validated based on a relatively small sample size. Another limitation is the expertise of practitioners who specialize in the U.S. Army's C5ISR systems. (Note: This is an opportunity for additional research with a larger sample size, as well as areas not related to the Army's C5ISR systems.)

In conclusion, this article provides new obsolescence management mental models to assist with the obsolescence mitigation for C5ISR systems. This research will strengthen the effectiveness of teams and organizations. Furthermore, this research complements other tools for mitigating obsolescence by deepening an organization's understanding of managing obsolescence in the context of several interwoven systems. Lastly, these obsolescence management mental models will contribute to a deeper understanding and better informed obsolescence-mitigation strategies by the system teams and their management.

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COST OVERRUN OPTIMISM: FACT or FICTION?

This article is a reprint of an article first published in *Acquisition Review Quarterly* (Winter 1994), Vol. 1, No. 1, pp. 25-38. It was revisited in the *Defense Acquisition Research Journal* (July 2015), Vol. 22, No. 3, pp. 254-271.

A WORD FROM THE AUTHOR

Cost overruns on major defense contracts continue to be a problem. I suspect the "abiding cultural program" described by Mr. Beach, is a primary causal factor. The need for cost realism and candor continues.

ORIGINALLY PRINTED
1994

Image designed by Ken Salter

Maj David D. Christensen, USAF (Ret.)

Program managers are advocates by necessity. When taken to the extreme, program advocacy can result in the suppression of adverse information about the status of a program. Such was the case in the Navy's A-12 program. In "A-12 Administrative Inquiry," Beach (1990) speculates that such "abiding cultural problems" were not unique to the Navy. To test that assertion, this article examines cost overrun data on 64 completed acquisition contracts extracted from the Defense Acquisition Executive Summary database. Cost overruns at various contract completion points are compared with projected final cost overruns estimated by contractor and government personnel. The comparison shows that the overruns projected by the contractor and government were excessively optimistic throughout the lives of the contracts examined. These results were found insensitive to contract type (cost, price), contract phase (development, production), the type of weapon system (air, ground, sea), and the military service (Air Force, Army, Navy) that managed the contract.

DOI: *https://doi.org/10.22594/dau.23-910.30.03*
Keywords: *comparison, management, performance, projected, realistic, time*

According to former Under Secretary of Defense for Acquisition, Technology and Logistics Jacques Gansler (1989, p. 4), the average cost overrun on a major defense contract has been about 40%. Although some of the causes of cost overruns are beyond the control of program managers, supporting an unrealistically low estimate of the final cost of a defense contract can only harm the program in the long run. The cancellation of the Navy's A-12 program in January 1991 is a highly publicized example of this problem.

Chester P. Beach (1990), the Inquiry Officer of the A-12 cancellation, reported that pessimistic projections regarding the program's cost were suppressed to protect the program and the careers of key managers. When Secretary of Defense Dick Cheney canceled the program in January 1991, he complained that no one could tell him its final cost (Morrison, 1991). In fact, there were many estimates of the program's completion cost: Some estimates were more than $1 billion higher than the ones supported by the government program office and by the contractors. The problem was the delayed and reluctant communication of the pessimistic estimates to key decision makers above the government program office. Although no one can say with certainty that the timely communication of more realistic estimates would have saved the A-12, it seems likely that at least part of the $1.35 billion in excess progress payments made to the contractors could have been avoided (Ferber & Math, 1991).

More realistic estimates and a culture that will tolerate them are needed. Program managers/directors are necessarily advocates of their programs. However, program advocacy is no excuse for suppressing critical information about a program's cost, schedule, or technical performance. In an acquisition policy letter, Assistant Secretary of the Air Force for Acquisition J. J. Welch (1991) wrote:

> A program director (PD) must be an advocate of his or her program … The PD's advocacy must not cross the line into attempting to "sell" the program, but must clearly be viewed as supportive to the user's requirements. The PD must articulate the pros and cons, as well as the "maturity curve" status, in a clear and comprehensive manner to preclude unfulfilled expectations or surprises. Such advocacy must be based on honesty and integrity to accurately portray program status.[1]

Regardless of this policy statement, Gansler (1989, p. 212) reports that the majority of program managers' time is spent "selling" their programs to budget committees. In addition, research has shown that, once a program is more than 15 to 20% complete, it is highly unlikely that the final cost overrun will be less than the present cost overrun (W. Abba, personal communication, 1992; Christensen & Payne, 1992; Heise, 1991; Wilson, 1991). Despite these facts, contractor and government program managers often claim optimistically that dramatic recoveries from cost overruns are possible.

Using information extracted from the Defense Acquisition Executive Summary (DAES) database, this article documents the optimistic forecasts of contract completion costs on 64 completed contracts. Average cost overruns at various contract completion points are compared with projected final cost overruns estimated by contractor and government personnel. The comparison shows that the overruns projected by the contractor and government were exceedingly optimistic throughout the lives of the contracts examined. These results were found insensitive to contract type (cost, price), contract phase (development, production), the type of weapon system (air, ground, sea), or the military service that managed the contract.

Background

Cost overruns and projected final overruns are regularly reported on cost management reports prepared by the contractor. These reports include the Cost Performance Report (CPR) and the Cost/Schedule Status Report (C/SSR). DoDI 5000.02, *Operation of the Defense Acquisition System* (2015),[2] stipulates that a CPR be submitted for contracts that require compliance with the DoD cost/schedule control systems criteria (C/SCSC) (DoD, 1991). For contracts not required to comply with the criteria, the C/SSR is usually required.[3]

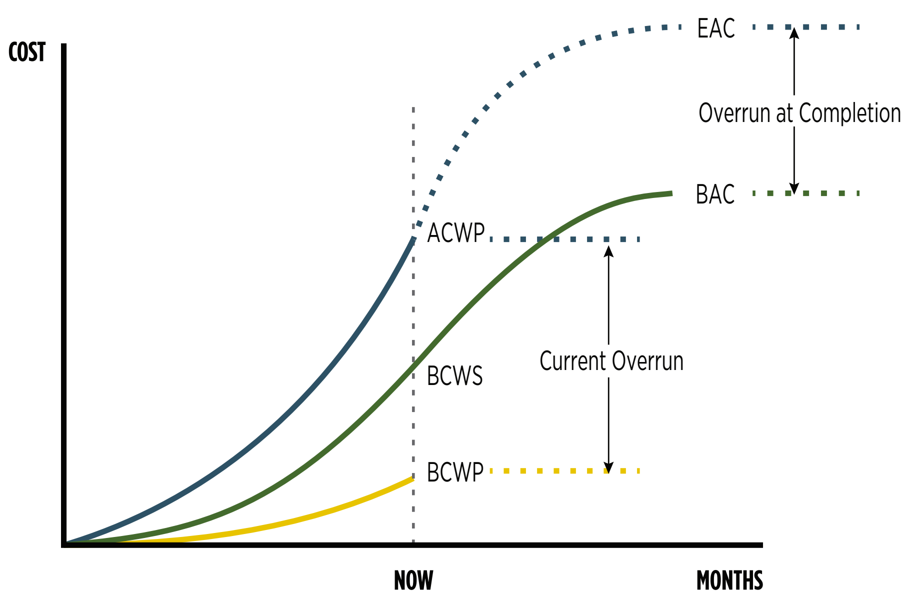
C/SCSC are not a management system. Instead, they establish minimal standards for the management control systems used by the contractor and have two objectives:

1. For contractors to use effective internal cost and schedule management control systems; and
2. For the government to be able to rely on timely and auditable data produced by those systems for determining product-oriented contract status (Department of the Air Force, 1989).

Implicit in these objectives is the assumption that, if the contractor's management control systems comply with the criteria, the data generated by those systems are reliable (Christensen, 1989).

Data summarizing a contract's cost and schedule performance are listed in the cost-management report. Key data elements of the report are shown in Figure 1. The budgeted cost of work scheduled (BCWS) is the sum of budgets allocated to time-phased elements of work on the contract, known as work packages and planning packages. The cumulative expression of these budgets, the performance measurement baseline, takes on a characteristic S-shaped curve. The end point of the baseline, the budget at completion (BAC), represents the total budget of all the identified work on the contract.

FIGURE 1. ADVERSE COST VARIANCE, TERMED COST OVERRUN



Note. AWCP = actual cost of work performed; BAC = budget at completion; BCWP = budgeted cost for work performed; BCWS = budgeted cost of work scheduled; EAC = estimate at completion.

> **The comparison shows that the overruns projected by the contractor and government were exceedingly optimistic throughout the lives of the contracts examined.**

As shown in Figure 1, the contractor also reports an estimate of the final cost of the contract, termed the estimate at completion (EAC). The EAC is an extrapolation of the cumulative actual cost of work performed (ACWP) to the end of the contract. If the projected final cost differs from the total budget, the contractor is predicting a cost overrun at completion. It is often revealing to compare the predicted cost overrun at completion to the present cost overrun. If the present overrun is worse than the predicted final overrun, the contractor is predicting effectively that the cost of the remaining work on the contract will be less than budgeted. For this article, the present cost overrun is defined as the difference between the cumulative budgeted cost for work performed (BCWP) and the cumulative ACWP (see Figure 1). The BCWP is the same number as BCWS, but is recorded when work is actually accomplished. Clearly, if the cost of the completed work exceeds the budget, a cost overrun is identified. If the cost overrun is significant, it is investigated to determine the cause. Hopefully, the timely and disciplined analysis of significant overruns will result in corrective action before the problems become serious.

The effectiveness of variance analysis depends on organizational culture. In a healthy culture a variance is considered an opportunity for improvement. In an unhealthy culture, a variance is bad news, and individuals or even organizations responsible for unfavorable variances may be punished. The result of this “shoot the messenger” culture can be the suppression of adverse information about a contract's status.

Although routine analysis in the A-12 program revealed adverse trends, the significance of the unfavorable cost and schedule variances was not revealed to senior civilian decision makers above the government program office. According to Beach (1990), the projected final completion costs supported by the contractor and the government program manager were unrealistic. For example, at the 37% completion point, the A-12 contractors reported a cost overrun of $459 million and a projected cost overrun at completion of $354 million (Abba, 1991).

The government program manager's estimated final overrun was slightly higher than the contractor estimate, yet less than the overrun to date.

Apparently, the need to present an optimistic picture was a dominant consideration that effectively suppressed more realistic estimates. Near the end of his report, Beach (1990) speculates that this "abiding cultural problem" was not specific to the A-12, but was a problem common to other major defense programs:

> There is no reason to believe that the factors which made these officials respond the way they did was unique to this military department. Indeed, experience suggests that they are not. Unless means can be found to solve this abiding cultural problem, the failures evidenced in this report can be anticipated to occur again in the same or a similar manner. (p. 27)

This article provides evidence that supports this assertion by examining available cost data on completed contracts.

> **In an unhealthy culture, a variance is bad news, and individuals or even organizations responsible for unfavorable variances may be punished. The result of this "shoot the messenger" culture can be the suppression of adverse information about a contract's status.**

Methodology

The purpose of this study was to determine if the overruns at completion projected by contractor and government personnel are unrealistically optimistic. Research has established that, once a contract is 15% complete, the final cost overrun will exceed the cost overrun to date (Abba, personal communication, 1992; Christensen, 1989; Heise, 1991; Wilson, 1991). Thus, a projected overrun at completion is defined as unrealistically optimistic if it is less than the present cost overrun.

To test the hypothesis, averages of the present cost overrun, the projected cost overrun at completion, and the final cost overrun were computed from a sample of 64 completed contracts extracted from the DAES database (DoD, 1991). This database contains contractor cost and schedule performance data on more than 500 defense contracts summarized quarterly by government program offices since 1970 (Christle, 1981). Because most of the contracts in this database are C/SCSC-compliant, the data are considered reliable.

Although the sampling technique was purely judgmental, the number and variety of contracts are considered sufficiently large to be general in nature. The period of performance for these contracts ranged from 1971 to 1991. Table 1 lists descriptive statistics on the average final cost overruns in the sample. For sensitivity analysis, the sample was divided into several categories, including contract type (price, cost), contract phase (development, production), the type of weapon system (air, ground, sea), and the Service managing the contract. For each category in the table, the number of contracts and the average, maximum, and minimum values for the final overrun are listed.

TABLE 1. FINAL COST OVERRUN ON 64 CONTRACTS

		PERCENT OF BUDGET			$ MILLIONS		
CATEGORY	**NUMBER**	**AVG**	**MIN**	**MAX**	**AVG**	**MIN**	**MAX**
Fixed Price	41	20	-3	109	34	-3	407
Cost	23	14	-1	46	41	-2	493
Development	25	21	-1	109	38	-2	407
Production	39	16	-3	46	35	-3	493
Air	43	18	-3	109	45	-3	492
Ground	13	21	5	45	23	7	42
Sea	8	12	0	38	12	0	36
Air Force	18	19	-1	109	49	-2	407
Army	28	20	-3	46	21	-3	46
Navy	18	13	0	46	41	0	493
ALL	**64**	**18**	**-3**	**109**	**36**	**-3**	**493**

Equations 1, 2, and 3 define the current cost overrun, the projected cost overrun at completion, and final cost overrun. Of the three overruns, only the projected cost overrun at completion is an estimate, showing the difference between the budget and the estimated completion cost. The others are simply the difference between the budget and actual cost of the work.

$$\textit{Current overrun (CO)} = \textit{Cumulative (Cum) BCWP} - \textit{Cum ACWP} \quad (1)$$

$$\textit{Overrun at completion (OAC)} = \textit{Contract budget base (CBB)} - \textit{EAC} \quad (2)$$

$$\textit{Final overrun (FO)} = \textit{CBB} - \textit{Final ACWP} \quad (3)$$

To normalize the data, the overruns were converted into percentages using Equations 4, 5, and 6. For the current cost overrun percentage, the cumulative BCWP was used. For the others, the CBB was used. The CBB is defined as the budget for all authorized work on a contract and includes the management reserve budget.

$$\textit{Current overrun percentage} = 100\times(CO/Cum\ BCWP) \quad (4)$$

$$\textit{Overrun at completion percentage} = 100\times(OAC/CBB) \quad (5)$$

$$\textit{Final overrun percentage} = 100\times(FO/CBB) \quad (6)$$

Each type of overrun (current, at completion, and final) was averaged for each category by dividing the number of contracts in that category into the total overrun for that category. The averaging was done at various stages of completion ranging from 10 to 100% completed (Equation 7).

$$\textit{Percentage completed} = 100\times(Cum\ BCWP/CBB) \quad (7)$$

Data earlier than the 10% completion point were not considered sufficiently reliable. It can take as long as 1 year from contract award for the contractor to demonstrate C/SCSC compliance. Until then, the data on the cost performance report are suspect.

As shown in Table 2 in null form, there were three hypotheses. Hypotheses H1 and H2 compare the average current overrun to the average overrun at completion by the contractor and government during various stages of contract completion. In hypothesis H3, the average overruns at completion by the contractor and government are compared.

TABLE 2. HYPOTHESES TESTED

	NULL HYPOTHESIS	INTERPRETATION
$H1_0$:	CO ≤ KOAC	Contractor's OAC not optimistic
$H2_0$:	CO ≤ GOAC	Government's OAC not optimistic
$H3_0$:	GOAC ≤ KOAC	Government more optimistic than contractor

Note. KOAC = contractor's overrun at completion; GOAC = government's overrun at completion.

If hypothesis H1 is rejected, the contractor's overrun at completion (KOAC) is unrealistically optimistic. If hypothesis H2 is rejected, the government's overrun at completion (GOAC) is unrealistically optimistic. If hypothesis H3 is rejected, the contractor is more optimistic than the government regarding the projected overrun at completion. A one-tailed "*t* test" was used to evaluate each hypothesis at the 95% confidence level.

Results

As illustrated in Figure 2, the hypotheses were generally confirmed. From as early as the 10% completion point, the optimism of the projected cost overrun at completion is apparent. Throughout the life of the contract, this estimate was found to be lower than the present and final cost overruns. Also note that the average overrun at completion projected by the contractor was more optimistic than the average overrun at completion projected by the government program office.

FIGURE 2. OVERRUN OPTIMISM (64 CONTRACTS)

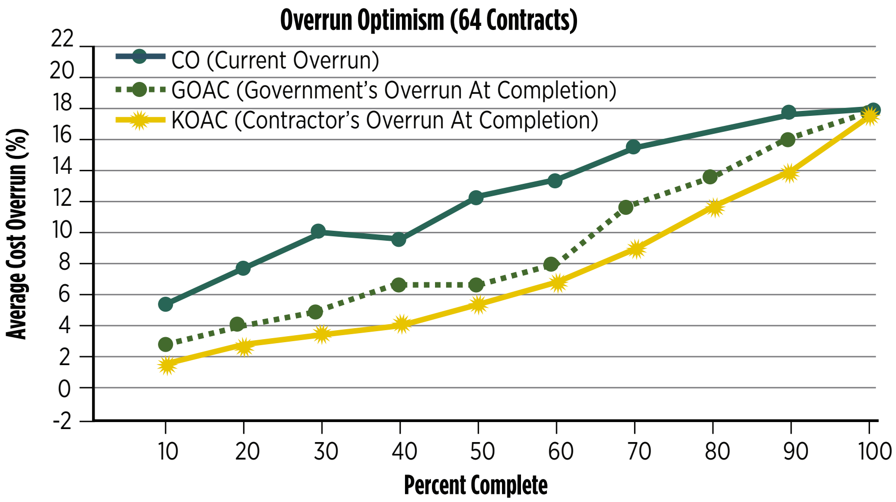
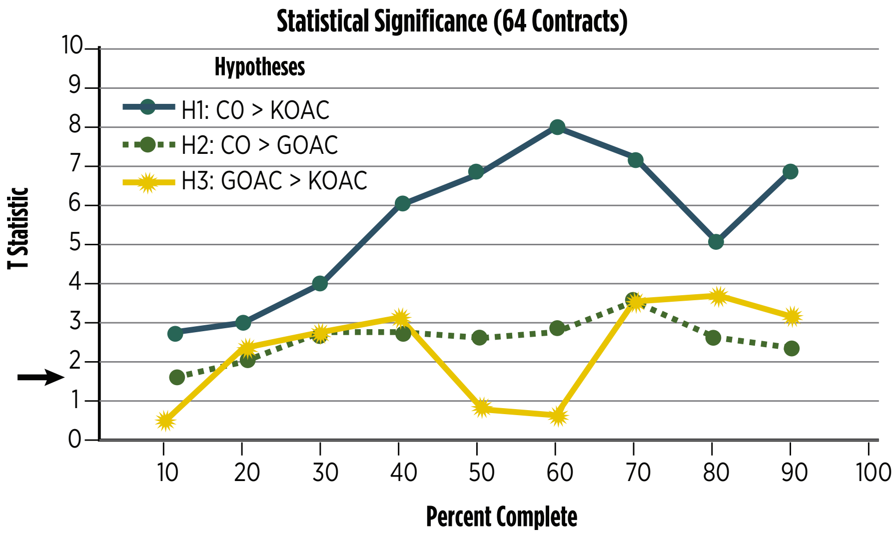


Figure 3 shows that the difference between the overruns is statistically significant through most stages of contract completion. When the one-tailed "*t* statistic" exceeds a critical value of 1.67 (t_a = .05 statistic > 1.67), the difference is defined as significant at the 95% confidence level.

FIGURE 3. HYPOTHESES CONFIRMED (FOR t_a= .OS STATISTIC > 1.67)



Note. KOAC = contractor's overrun at completion; GOAC = government's overrun at completion.

As illustrated in Figures 4 through 6, these results were generally insensitive regarding the contract type, contract phase, type of weapon system, and the military service that managed the contract. To facilitate comparisons, the scales of the graphs are the same. The statistical significance of the differences between the overruns was generally confirmed for each category examined. The details, however, are not reported here.

FIGURE 4. AVERAGE COST OVERRUNS BY CONTRACT TYPE

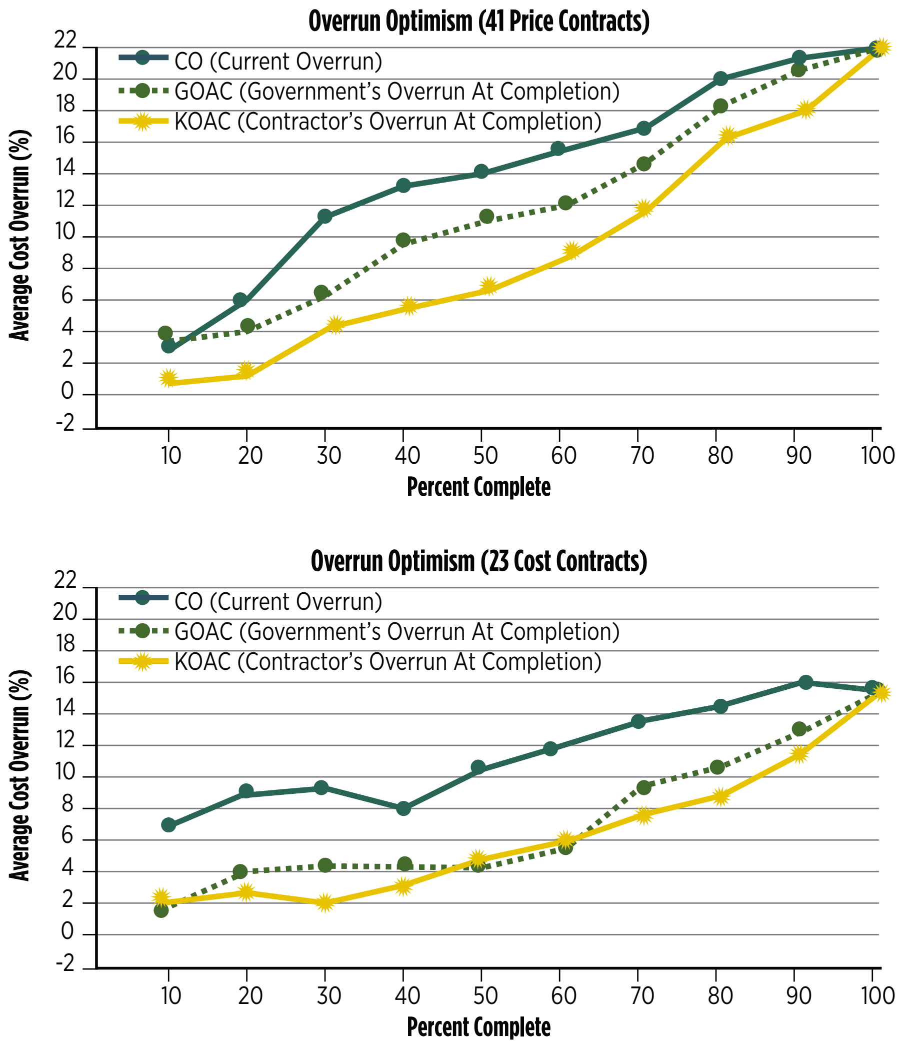
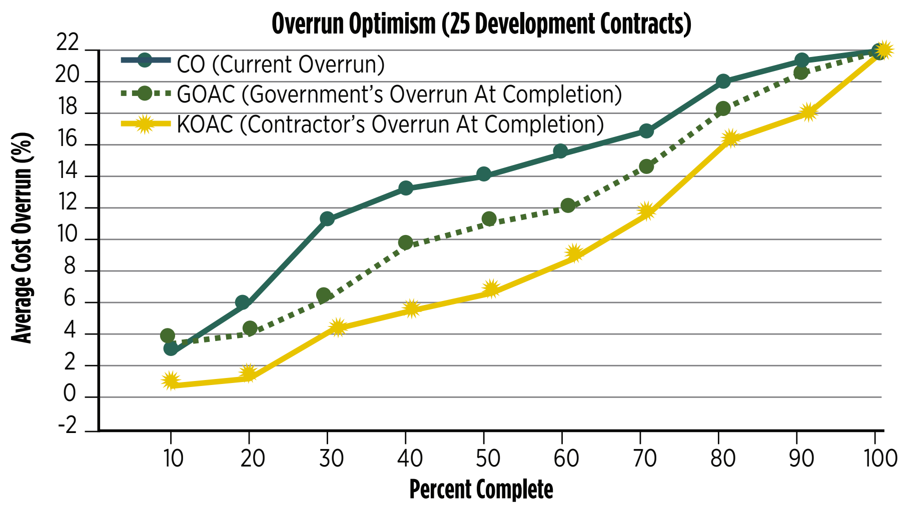


FIGURE 5. AVERAGE COST OVERRUNS BY CONTRACT PHASE



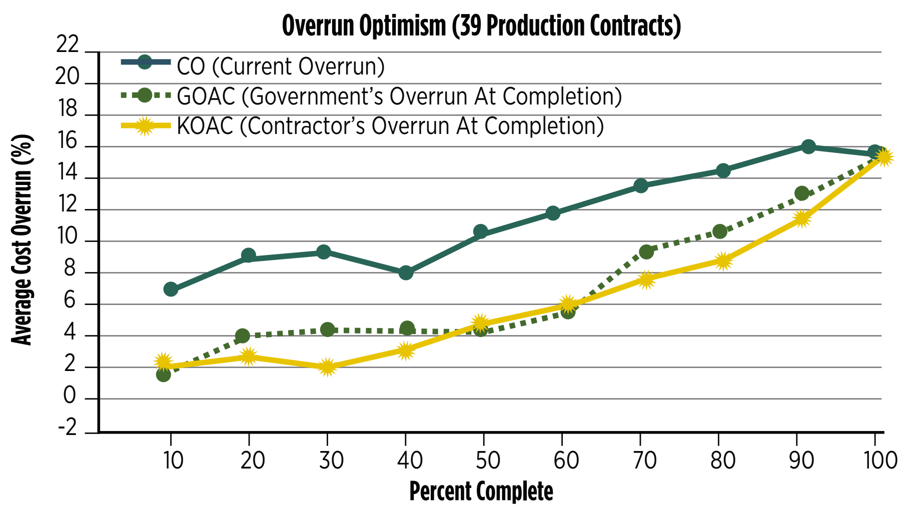
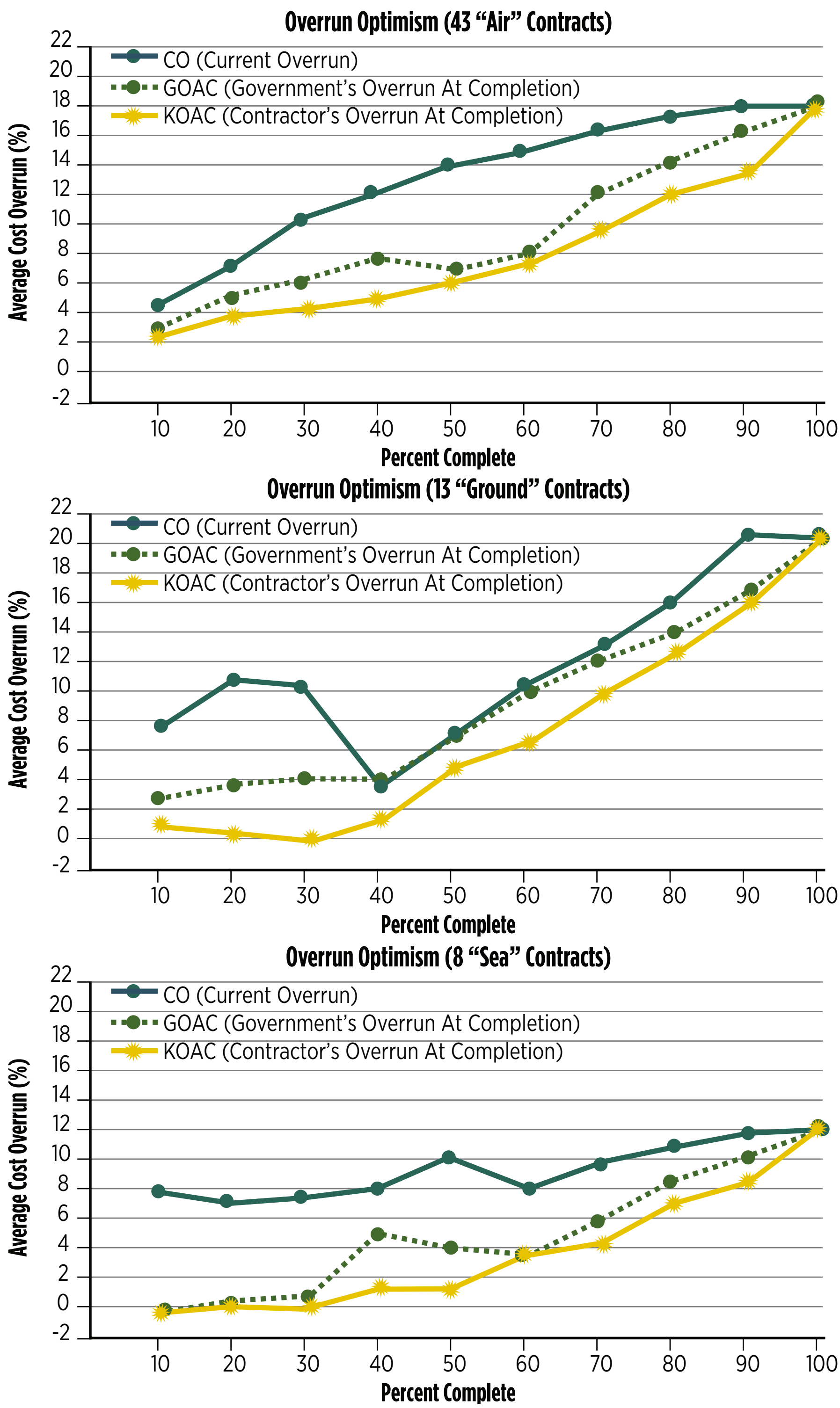


FIGURE 6. AVERAGE COST OVERRUNS BY TYPE OF WEAPON SYSTEM



Conclusion

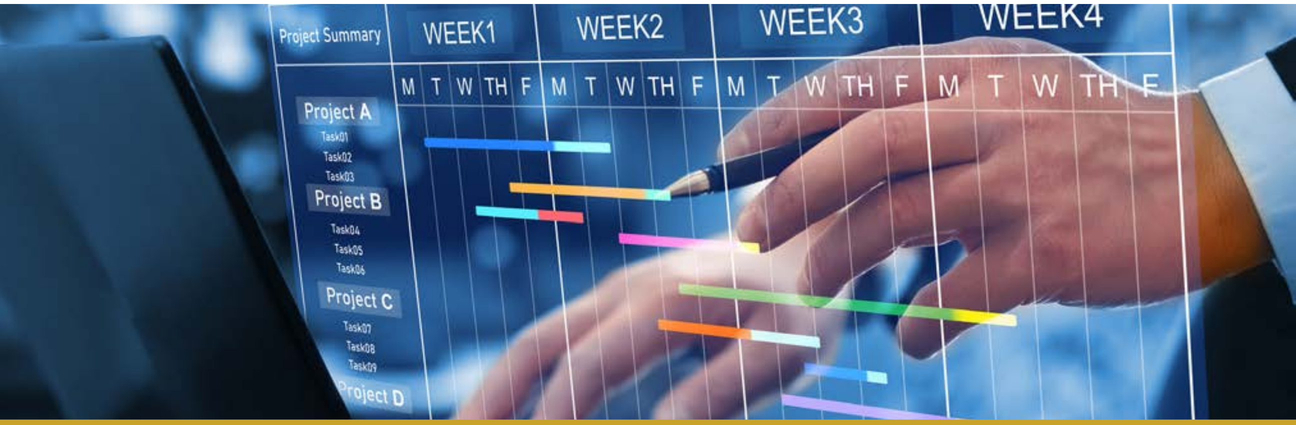
Based on an analysis of 64 completed contracts, the overruns at completion predicted by the contractor and by the government program office were unrealistically optimistic. From as early as the 10% completion point through the end of the contracts, the predicted final overruns were less than the current overruns reported on the contracts.

Although the estimates supported by the government program offices were less optimistic than the contractors' estimates, neither was found to be realistic.

Donald J. Yockey (1991), then Under Secretary of Defense (Acquisition), called for more realism throughout the acquisition process, including estimating realism.

> We can't afford to understate, sit on, or cover up problems in any program—at any time, at any level. They must be brought forward. This includes not just *show stoppers* but also *show slowers*. I can't stress this strongly enough. (p. 36).

In an interview between the author and Wayne Abba, a respected analyst at the Office of the Under Secretary of Defense (Acquisition), Abba commented that adverse trends can be reversed if management pays attention to them (W. Abba, personal communication, 1992). Until contractors and program offices are willing to support and advance realistic assessments of a program's status, the attention and expertise of upper level management is postponed, undoubtedly, in the long run, to the detriment of the program and nation. The famous economist Keynes once stated that, in the long run, we are all dead (Horngren & Foster, 1991). Postponing or hiding adverse information about a program may be an effective short-run strategy; but, in the long run, it could result in cancellation of the program.



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Endnotes

[1] Responses from an interview with J. J. Welch, which appeared in Acquisition Policy Letter 91M-005, April 8, 1991.

[2] *DoDI 5000.02, Operation of the Defense Acquisition System (2015)* is now superseded by DoDI 5000.02, *Operation of the Adaptive Acquisition Framework* (2020), with Change 1 (2022).

[3] Compliance with C/SCSC is required on significant contracts and subcontracts within all acquisition programs. Significant contracts are research, development, and test and evaluation contracts with an estimated cost of $60 million or more (in fiscal 1990 constant dollars) or procurement contracts with an estimated cost of $250 million or more (fiscal year 1990 constant dollars) (DoD, 1991, p. 11–B-2).

Author Biography

MAJ DAVID S. CHRISTENSEN, USAF (RET.)

is a Professor of Accounting and Ethics, Department of Accounting and Finance, at Southern Utah University. He has a PhD from the University of Nebraska-Lincoln. He taught earned value management systems and cost management at the Air Force Institute of Technology for 10 years. He retired as a major in the US Air Force in 1995. He has published over 70 peer-reviewed research articles on cost management and business ethics. His current research interests are in accounting ethics.

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REMEMBERING GREG CARUTH

A LIFE BY DESIGN

Greg reviews a printed copy of Program Manager *magazine fresh off the press, early 1980s.*
DSMC photo

Greg Caruth, former art director for *Program Manager* magazine, and director, DAU Visual Arts and Press, died suddenly on June 28, 2023.

By the time he retired in 2003, Greg had been the Visual Arts and Press Director for so many years no one could remember when he wasn't around. He was one of the original Air Force cadre assigned to Defense Systems Management School (DSMS) and served in a military or civilian capacity over the years under the leadership of all but one of the 15 Defense Systems Management College (DSMC) commandants, two DAU commandants, and two DAU presidents.

Greg was an integral part of ensuring the continuity of the DSMS, DSMC, and DAU identity as he lived the transition of DSMS from a school to a college in 1976, and from a consortium college to a corporate university and subsequent consolidation with DAU in 2000.

Returning to DSMS in 1979, which by then had become DSMC, he became the supervisor of DSMC Visual Arts. In 1995, he became director of DAU Visual Arts and Press when the college Press and Visual Arts departments merged.

Greg was a dependable, steady presence and extremely talented artist and sculptor—traits he put to good use while leading DAU's publishing group and creating design elements that still grace the DAU main campus at Fort Belvoir, VA.

He was best known for his nationally recognized exhibits and posters at major military conference venues throughout the DC metropolitan area. Greg used his considerable skill and vision to tie the DAU education experience to "talk of the town" exhibits that featured the likes of Egyptian pharaohs, Stone Age replicas, Sun Tzu, Uncle Sam, Leonardo de Vinci, and many more.

When he arrived at his retirement luncheon in 2003 in a white limousine, a gift from his staff, a constant refrain was heard among the crowd: "Who will they ever get to replace Greg?" Shortly after his retirement, he was nominated and won entry into the DAU Hall of Fame.

Greg loved life, loved travel with his wife Rita (who preceded him in death two years ago), loved art, and loved a good pun. Not surprisingly, in retirement he continued his passion for design and began creating realistic Christmas manger scenes, which are highly prized by those who knew him.

Greg earned admiration, respect, and friendship at DAU, not only from leaders and colleagues, but also from the many employees he supervised over the years. He truly lived a life of design—and DAU still reaps the rewards of his legacy.

Greg displays the sculpted bust he created for the dedication of the Packard Executive Conference Center in honor of former Deputy Secretary of Defense David Packard. The dedication coincided with the 25th Anniversary of the Defense Systems Management College, June 25, 1996.
DSMC photo

Greg is inducted into the DAU Hall of Fame in April 2005 by then DAU President Frank Anderson at the Fort Belvoir, VA, Officers Club.
DAU photo

PROFESSIONAL READING LIST

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

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

Featured Book

Leading With AI and Analytics: Build Your Data Science IQ to Drive Business Value

Author: Eric Anderson and Florian Zettelmeyer

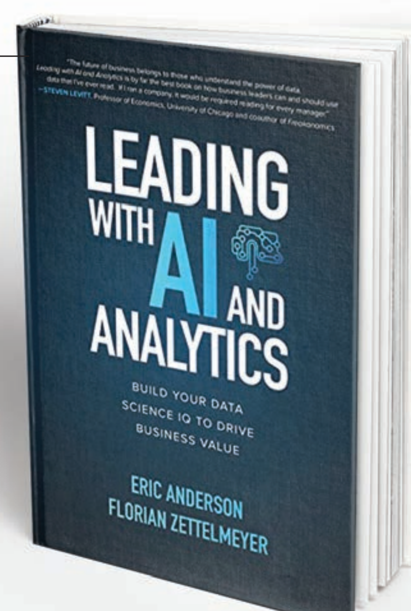
Publisher: McGraw-Hill

Copyright Date: 2020

Hard/Softcover/Digital: Hardcover, 352 pages

ISBN-13: 9781260459142

Reviewed by: Philip Broyles



Review:

The authors' purpose in this book is to increase leaders' Data Science Intuition Quotient (DSIQ), which refers to one's working knowledge of data science. This book illustrates the notion that data analytics and artificial intelligence (AI) are a leadership problem and argues that analysts create value for organizations through "IEE"—ideas or ideate, enable, and evaluate. Throughout, this theme is revisited by examining roles of both business leaders and data scientists. The business leader must understand how data science works; the source from which data are derived; how to intuitively question results and methodologies; and, most importantly, how to steer the organization and frame the questions that guide data science. The authors state that leaders and managers must establish a truth-in-data standard and ensure that the data used meet this standard to avoid a manager throwing a "data quality penalty flag" because they disagree with the output. The text is populated with useful maxims throughout. The authors demystify AI, machine learning (ML), and analytics by providing a logical progression through the topics without diving too deeply into technical details. Their mantra is that leaders can use their intuition and data science insights to create value and wins for their organizations.

Numerous factual and fictional examples permeate the reading to aid in understanding the field of data analytics. The authors methodically remove the veil of complexity from AI and ML by breaking industry buzzwords into comprehensible descriptions of the tools and vocabulary necessary for readers to grasp. They further break down data analytics into three primary categories—exploratory, predictive, and causal—and emphasize the need for variability in processes to make the data more meaningful.

Fundamental building blocks of data analytics are provided throughout the text. These include data itself; statistical tools such as linear regression, multilinear regression, and logistics regression; neural networks; tests for goodness of fit for the data; as well as experiments, natural experiments, and quasi-experimental design. The authors also further break down ML into supervised and unsupervised categories and give examples of ML tools such as decision trees, random forests, and *XGBoost*. Furthermore, AI is described in one of two categories: (a) symbolic (aka rules-based AI, the most common early attempts in this field); and (b) ML-type, where the machine is fed data and develops the ability to learn from the data, thus creating outputs as it moves through vast amounts of data using algorithms to do so. Finally, the authors provide examples of common pitfalls leaders may face when looking at data and associated outputs (e.g., dashboard views), how to remove barriers within an organization to fully embrace artificial intelligence and analytics (AIA), and how to build successful teams. The book concludes with five vignettes of major companies that learned to embrace AIA for success.

For defense acquisition professionals, analytics must be problem-driven and planned upfront. The authors make a clear linkage from Key Performance Indicator (KPI) development to data sourcing and alignment to AIA that provides the answers to questions that directly support realization of the organizations' KPIs and core objectives.

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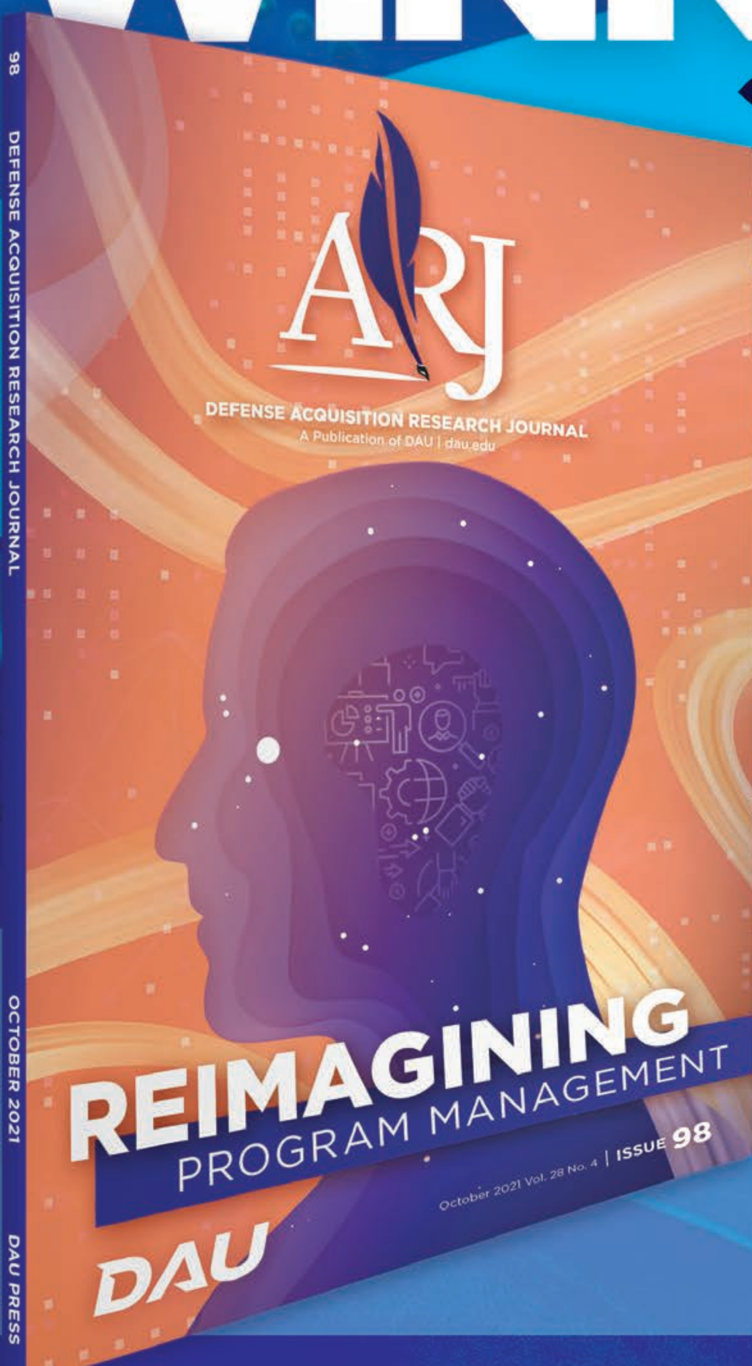

Emily Beliles, Norene Johnson, and Nicole Brate

DAU Press

Fort Belvoir, VA

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Current Research Resources in DEFENSE ACQUISITION

Leading Change

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

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

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

Culture Change and People First: Creating a Culture that Acts as the Antibody to the Corrosive Elements

LTC Michael Soyka, USA

Summary:

The U.S. Army announced a series of "People First" initiatives in the wake of the 2020 Report of the Fort Hood Independent Review Committee. The report provided a scathing indictment of the culture that existed at Fort Hood, which allowed the counterproductive elements of sexual assault, suicide, and racial extremism to fester. Army initiatives sought to change not just the climate of organizations but the entire culture, stating "we must define, drive, and align our culture with our vision of cohesive teams." The Army, however, is composed of vastly differing organizations, and the strategic imperative of removing harmful behaviors collides with the realities of missions and constraints at the battalion and brigade levels. The Army currently struggles with a recruiting problem that has forced Army senior leaders to adjust the end strength of the Army and could cause a deficit of as many as 30,000 soldiers below its required number by 2023. The Army is contending with many reasons for those recruiting issues, including the low percentage of America's youths who are eligible to enlist and a difficult job market, but internal to

the Army we must acknowledge that part of the problem lies with the culture of our units. If potential recruits hear horror stories from enlisted soldiers and the headlines parents read are filled with stories of counterproductive leaders, then recruitment will continue to be a challenge.

Many leaders across the Army have a desire to change their culture to better meet the dual needs of maintaining readiness and minimizing harmful behaviors. However, lack of a systemic method of understanding what needs to change impedes how Army leaders can go about making meaningful and long-lasting changes to the culture of units. Over the last 2 years, the leaders of 1st Battalion, 77th Armored Regiment (1-77 AR) embarked on a planned cultural change to better align its actions, values, and culture to both increase its organizational effectiveness and meet the imperative of reducing harmful behaviors. This change is still ongoing in the organization, but some changes it made and the overarching methodology may be useful to other leaders who are trying to replicate the regiment's efforts within their own organizations.

APA Citation:

Soyka, M. (2023). Culture change and people first: Creating a culture that acts as the antibody to the corrosive elements. *Military Review, 103*(3), 67–79. https://www.armyupress.army.mil/Journals/Military-Review/English-Edition-Archives/May-June-2023/Culture-Change-People-First/

Leadership in the Implementation of Change: Functions, Sources, and Requisite Variety

Jeffrey Ford, Laurie Ford, and Beth Polin

Summary:

Despite the prevailing perception that leadership is essential to successful organizational change, reviews of empirical research on the subject reveal inconsistencies in the approaches to, and measurements of, both leadership and its impact on change outcomes. The study and development of leadership should reach beyond the simple focus on individual leaders and ultimately broaden our view of how the most meaningful impact can be made.

Toward this end, this article provides a general framework of leadership in the implementation of change. Starting from a functional perspective, the authors assert that leadership is provided by one or more leadership sources that independently or collaboratively enact a configuration of four leadership functions through specific behaviors from three behavioral metacategories. They also posit that leadership effectiveness—and the success of change—are products of the degree to which the configuration of functions, enacted sufficiently,

addresses the variety of situations leadership sources encounter. In this regard, the integrative framework offered therein focuses primarily on what Joseph Rost, in his *Leadership for the Twenty-First Century* (1991), categorizes as the peripheral elements of leadership theory.

APA Citation:

Ford, J., Ford, L., & Polin, B. (2021). Leadership in the implementation of Change: Functions, sources, and requisite variety. *Journal of Change Management, 21*(1), 87–119. http;//doi.org/10.1080/14697017.2021.1861697

Kotter's Change Model in Higher Education: Transforming Siloed Education to a Culture of Interprofessionalism

Jan Odiaga, Mary Jo Guglielmo, Cathy Catrambone, Theresa Gierlowski, Chris Bruti, Lynette Richter, and Joanne Miller

Summary:

Culture transformation of an academic medical center, with its "siloed" education and hierarchal structure, is a difficult and slow process. The application of Kotter's Accelerated (XLR8) Business Change Model transformed a siloed academic organization's culture to one of interprofessionalism. Pressed to effect rapid and sustainable change in an academic medical center, strategies from the XLR8 model were applied to the hierarchal culture. All the accelerators of the XLR8 model were consciously applied to the change process. Institutional cultural change was validated after the academic medical center implemented the following actions:

- Development of an Interprofessional Education (IPE) curriculum was chosen and approved as a quality improvement initiative for accreditation by the Higher Learning Commission.
- Leadership (president and provosts) funded an Office of Interprofessional Education, including a faculty and support personnel work effort resulting in a yearlong IPE course.
- IPE was included in the center's vision, mission, and strategic plan.
- Four colleges were unified.
- A designated time was reserved for IPE.

- A requirement for completion of IPE was established for graduation as well as IPE's subsequent addition to student transcripts.

Kotter's accelerated model of change is an effective method to remove barriers to educational cultural change. Using Kotter's change theory model as an infrastructure for change, a large Midwest academic medical center advanced the culture of interprofessionalism via the development of an IPE curriculum embedded within the university. Kotter's business model was successfully implemented in a hierarchal academic medical center. Likewise, and if other change agents have a clear and deep understanding of the organizational culture, educational institutions with similar cultural structures could use this change strategy to achieve successful outcomes. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

APA Citation:

Odiaga, J., Guglielmo, M. J., Catrambone, C., Gierlowski, T., Bruti, C., Richter, L., & Miller, J. (2021). Kotter's change model in higher education: Transforming siloed education to a culture of interprofessionalism. *Journal of Organizational Culture, Communications and Conflict, 25*(2), 1–7. https://www.abacademies.org/articles/kotters-change-model-in-higher-education-transforming-siloed-education-to-a-culture-of-interprofessionalism-10343.html

Change Agent

Michael Bold

Summary:

First as a professor at Harvard Business School, and now as a professor emeritus and as co-founder and chairman of Kotter International, a consulting company Dr. John P. Kotter started as a result of positive response to his research, he has become the "go-to" authority on leadership and change.

> When it comes down to tactics, what we've learned ... is that if you get a group of people who understand the basic argument—in [the Army's] case, how much the world has changed since the traditional system for acquiring new systems, weapon systems and the like, and the time horizon that was acceptable, how much that is out of line with current reality—that's something really—the word revolutionary is not a big overstatement.

If the leader couldn't explain the vision in 5 minutes, Kotter further explained:

> It usually meant that it was just not clear in their own heads, which means their capacity to communicate it and make it clear in

> anybody else's heads, much less get them excited about it, just wasn't there. Because a vision is not an operating plan.

On the other end of the spectrum are organizations (such as the Army), according to Kotter, that "keep the number of people who are in a sense empowered to help produce change small and controllable," without recognizing that a strict hierarchical organization is "built much more to produce efficiencies and reliability just to get the job done."

APA Citation:

Bold, M. (2019). Change agent. *Army AL&T Magazine*, 71–77. https://asc.army.mil/web/news-alt-amj19-change-agent/

Leading Collaborative Change in an Educational Organization

Eric. K. Kaufman, Shreya Mitra, James C. Anderson II, Jama S. Coartney, and Carol S. Cash

Summary:

Organizations can effectively apply a variety of strategies for leading and accelerating desired change. As a practical illustration, this article evaluates an organizational change effort within the U.S. Department of Defense Education Activity (DoDEA), analyzing the restructuring of its worldwide school system through Kotter's accelerators for leading change. A cornerstone of DoDEA's effort was the creation of three Centers for Instructional Leadership (CILs), tasked with improving student achievement by developing educational leadership and supporting instructional excellence. The development of DoDEA's CILs presents a valuable case for understanding the leadership necessary for successful organizational change, particularly by leveraging the use of Kotter's Accelerated (XLR8) Business Change Model.

APA Citation:

Kaufman, E. K., Mitra, S., Anderson II, J. C., Coartney, J. S., and Cash, C. S. (2019, October). Leading collaborative change in an educational organization. *Journal of Leadership Education*, *19*(4), 56–67. https://doi.org/10.12806/V19/I4/R5

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/.

As the Defense ARJ is an open-access publication, authors should be mindful of using any resources in their research that are classified or otherwise circulation-restricted. If one or more circulation-restricted sources are critical to the manuscript, the author should indicate these upon submission.

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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.

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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.

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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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- The author requires that the usual copyright notices be posted with the article.
- To publish the article requires copyright payment by the DAU Press.

Print Schedule

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Issue	Submission Deadline
January	July 1
April	October 1
July	January 1
October	April 1

Submissions

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 2 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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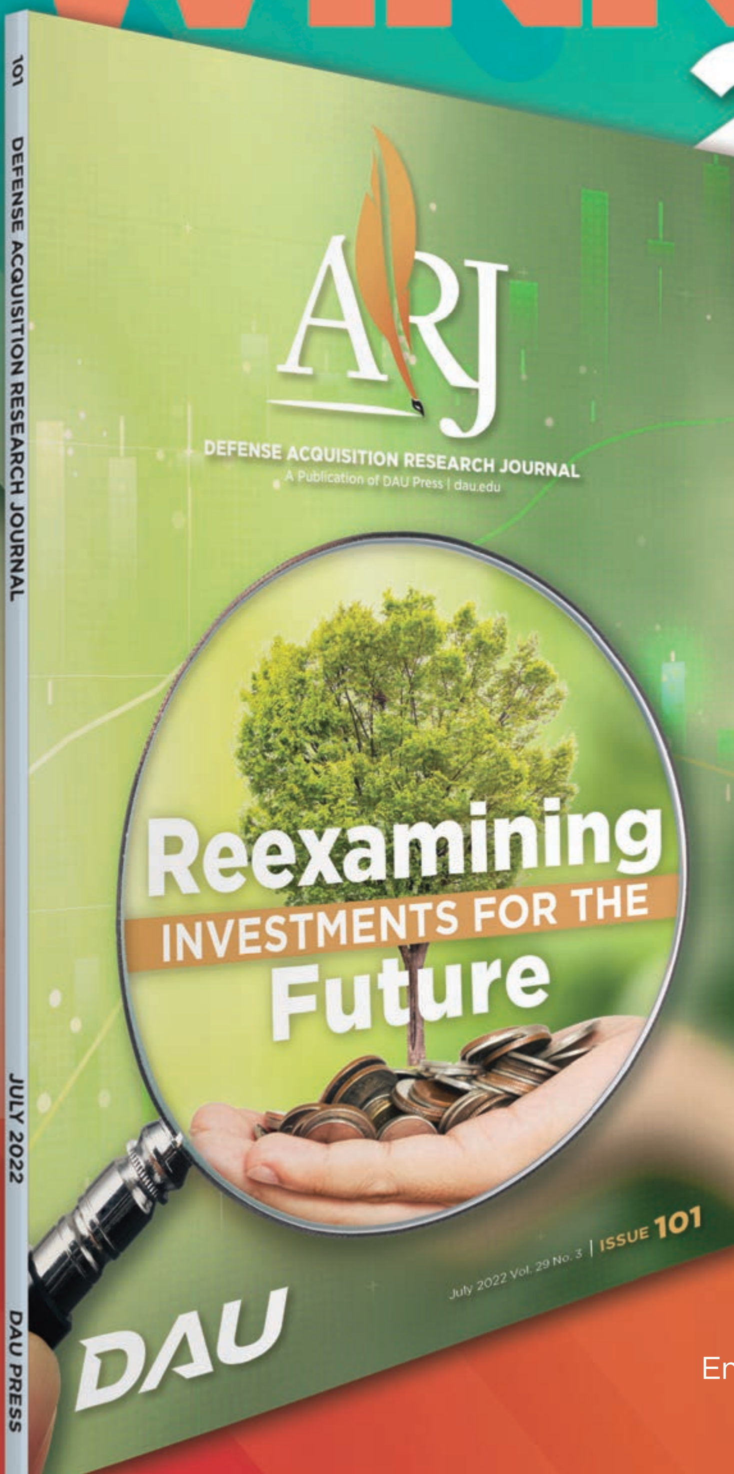

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