Visualization Tool for Obsolescence Management: Reducing Supply Chain Risk for C5ISR Systems
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Defense Industrial Base: Acquisition Program Case History
COL Robert F. Mortlock, USA (Ret.)

The Defense Acquisition Professional Reading List
Becoming a Data Head: How To Think, Speak, and Understand Data Science, Statistics, and Machine Learning
Written by Alex J. Gutman and Jordan Goldmeier and reviewed by Philip Broyles
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Defense Industrial Base: Acquisition Program Case History

COL Robert F. Mortlock, USA (Ret.)

This case history centers on the capability and capacity of the Defense Industrial Base to develop and produce body armor for Warfighters. Considerations include the balancing of limited resources against competing priorities, sustaining inventory for wartime readiness, managing the demand for increased capability, and balancing surge requirements with industry capacity.

Visualization Tool for Obsolescence Management: Reducing Supply Chain Risk for C5ISR Systems

Matthew D. Chellin and Erika E. Gallegos

This article demonstrates a novel obsolescence management tool to assist with the data visualization of component obsolescence. The tool is widely applicable and can be used to inform the obsolescence management approach from a small team to a large organization.
From the Chairman and Executive Editor

Call for Authors

We are currently soliciting articles for the 2024 Defense Acquisition Research Journal (ARJ) print year. Please see our guidelines for contributors for submission deadlines.

From the Editors: How to Get Your Manuscript Published

The authors examine the process of publication and peer review in Defense ARJ and provide tips on how to produce a strong journal submission. They discuss Defense ARJ’s submission guidelines, a strong research question, structure of an article, and writing style.

Written by Olena McLaughlin and Christopher McGowan

Professional Reading List

Becoming a Data Head: How To Think, Speak, and Understand Data Science, Statistics, and Machine Learning.

Written by Alex J. Gutman and Jordan Goldmeier and reviewed by Philip Broyles

Current Research Resources in Defense Acquisition

A selection of new research curated by the DAU Research Center and the DAU Virtual Research Library.

Defense ARJ Guidelines for Contributors

Defense ARJ is a scholarly peer-reviewed journal published by DAU. All submissions receive a blind review to ensure impartial evaluation.

Statement of Ownership

Recognition of Reviewers 2023
The theme of this issue is “Think Innovation.” It is not only the topic of this issue’s Current Research Resources in Defense Acquisition, but also a call for action that underscores the main idea present in the articles—critical and innovative thinking. Innovation is the driving force of any research; critical and innovative thinking allows defense acquisition professionals to generate new solutions to improve the acquisition process and outcomes.

The first article, “Defense Industrial Base: Acquisition Program Case History,” by Col Robert F. Mortlock, is a case history that examines the challenges of the Defense Industrial Base (DIB) in procuring body armor for Warfighters. The analysis focuses on the capability and capacity of DIB and delves into the complicated stakeholder environment to extrapolate the lessons in project management, resulting in improved analysis for the DIB. The author urges that considering perspectives of all stakeholders and applying such
analysis techniques as comparison tables, decision matrices, and cost-effectiveness studies benefit all involved parties.

The second article is “Visualization Tool for Obsolescence Management: Reducing Supply Chain Risk for C5ISR Systems,” by Matthew D. Chellin and Erika E. Miller. The authors introduce an innovative visualization tool, developed using the R statistical software program, to measure a system’s level of obsolescence risk. The authors suggest a wide applicability of the tool in the effort to manage obsolescence both in small teams and large organizations.

In addition, in this issue, our managing editor Olena McLaughlin and assistant editor Christopher McGowan take the opportunity to provide some tips on producing a high-quality manuscript for a potential publication in *Defense Acquisition Research Journal (ARJ)*. In the editorial “From the Editors: How to Get Your Manuscript Published,” they explain *Defense ARJ* guidelines, make suggestions as to style and structure of a submission, and go over the peer review process in more detail.

The issue’s Current Research Resources in Defense Acquisition focus on innovation.

The featured work in the Defense Acquisition Reading List book review is *Becoming a Data Head: How To Think, Speak, and Understand Data Science, Statistics, and Machine Learning*, by Alex J. Gutman and Jordan Goldmeier, reviewed by Philip Broyles.

We take this opportunity to inform our readership that in the 2024 publication year, *Defense ARJ* will publish issues semiannually, in April and October.
call for
AUTHORS

We are currently soliciting articles for the 2024 Defense Acquisition Research Journal (ARJ) print year.
We welcome submissions describing original research or case histories from all acquisition career fields and phases of the acquisition life cycle—the conceptualization, innovation, initiation, design, testing, contracting, production, deployment, logistics support, modification, and disposal of weapons and other systems, supplies, or services (including construction) needed by the DoD or intended for use to support military missions.

Articles of 5,000 words or fewer appear in both print and digital publications. Articles of 5,000 to 10,000 words will be considered for digital publication only. All manuscript submissions are peer reviewed.

All submissions should include the following items:

- Cover letter
- Manuscript
- Figures and tables
- Biographical sketch for each author
- Headshot for each author

Benefits of publishing:

- Share your research results with the defense acquisition community.
- Change the way DoD does business.
- Become a nationally recognized expert in your field or specialty.
- Earn a promotion or award.
- Be invited to speak at a conference or seminar.
- Earn up to 40 continuous learning points.

For more information, contact the Defense ARJ managing editor (DefenseARJ@dau.edu) and check out our Guidelines for Contributors at https://www.dau.edu/library/arj/defense-arj-submissions
Research publication is often challenging for prospective authors but necessary for them to introduce their research, contribute to the conversation in their field, and advance their field of study. In this article, editors of Defense Acquisition Research Journal (ARJ) offer advice to defense acquisition professionals aspiring to publish in Defense ARJ and point out some caveats in the research publishing process. The editors also explain what kind of articles the journal publishes and summarize how to produce a strong submission. This article discusses Defense ARJ’s guidelines for contributors in more detail, explains the structure and style submissions should follow, and explains the peer review process.

DOI: https://doi.org/10.22594/dau.23-917.31.01

Keywords: Defense ARJ, submission, guidelines, research question, writing style, publication, peer review
While research is important for advancement of scientific achievement, publishing the results of said research is equally vital because it allows both the authors and the readers to participate in the ongoing scientific conversation. It is integral to the health of the academic community and the researchers’ success. Producing a publishable manuscript, however, is not an easy task. It is often so much more exciting to conduct the research than to compress and format it into a print-ready article. This article contains advice on how to produce a manuscript potentially publishable in *Defense Acquisition Research Journal (ARJ)*.

### Background

Empirical research is extremely time consuming and represents a great investment on the part of researchers; for this reason, it is crucial for authors to get their work acknowledged by their specific field. “Journals are where the results of new research are published for rigorous examination by the academic community” (Kekäle et al., 2009, p. 71). Remember that as an author, you are entering a scientific dialogue that is already ongoing. Waks (2005) calls for “contributions to knowledge” and stresses that “scholarship is a communicative and cooperative, not isolated and individual, activity. ‘Contributions to knowledge’ are better thought of as being like timely contributions to ongoing conversations. They are relevant and useful only to specific audiences at specific times” (p. 639). While authors should always consider larger implications and applications of their research, keep in mind that “Contributions to knowledge, like those to any conversation, are directed not to any and every one at any and every time, but to specific others joined at a particular time in the conversation, sharing overlapping interests and concerns” (Waks, 2005, p. 639). In other words, be mindful of the scientific community you call your own when producing a manuscript for publication.

To be of value and meaningfully contribute to the conversation, ensure that you are versed in what has been “said”; in other words, conduct a literature review on your chosen topic: ideas, terms, frameworks, languages, theories, etc. Identify the
gaps and open questions exposed in your literature review that need to be filled. “To contribute to knowledge … is to address these open and interesting questions, to share with these audiences in the process of advancing contemporary, collective understanding through this give and take of ideas” (Waks, 2005, p. 639). This is where your literature review is essential as it allows you to briefly recap what has been said in the conversation and identify your niche, the question you are attempting to answer, and the gap you are intending to fill.

“Be mindful of the scientific community you call your own when producing a manuscript for publication.”

Peruse the Guidelines

When shaping an article, it is imperative to consider your readership and the guidelines of the journal to which you would like to submit your manuscript for review. Gilmore et al. (2006, p. 470) compiled a few questions as guidelines for authors in any field of research:

- Is the topic appropriate for this journal?
- Are the style, layout and length appropriate?
- Is the research method employed in empirical work appropriate?
- Are the empirical findings meaningful and insightful?
- Does the article make a meaningful contribution to knowledge?

Structure your submissions appropriately according to the guidelines of the journal. Knowing your journal of choice is crucial. Most research is not ready to be published as is. Keep in mind at all times to connect your research, the data you have compiled, and your results to current concerns in the field. Discuss implications and possibilities for future research.
Consider looking at the abstracts from previous issues of the journal or browse the articles to get a better understanding of what kind of material the journal publishes. Pay close attention to the subject matter on which the journal typically focuses, the types of papers the journal publishes, and the structure of the articles the journal requests. However, do not disregard the small details, such as a particular style of formatting, use of endnotes vs. footnotes, formatting of reference lists, etc. Tailor your submission to the journal of your choice vs. a generic journal. Although many journals will still consider an article that is formatted incorrectly as long as its contents are appropriate for the particular journal, submissions that closely follow the journal’s guidelines look more professional and are appreciated by the editors. In addition, these more polished articles go on to be accepted at a higher rate than submissions that lack the same attention to detail. Since September 2018, articles presented to Defense ARJ whose initial submissions closely followed the provided submission guidelines were accepted at a rate of 60%, 12% higher than those who did not follow submission formatting guidelines (48%). While this adherence to formatting guidelines likely is not the source of these articles’ improved performance in and of itself, nevertheless, a clear correlation exists between an author’s attention to detail and their likelihood of publication in Defense ARJ.

Defense ARJ publishes papers that represent original empirical research or case histories related to the defense acquisition process. Its primary readership is the defense acquisition community. “Defense acquisition is broadly defined as any actions, processes, or techniques relevant to 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” (Defense Acquisition University [DAU], n.d.). Defense ARJ considers manuscripts that engage one or more of the areas of acquisition. The journal does not publish position papers, literature overviews, essays, or other types of papers that are not grounded in empirical data.

Research manuscripts published by Defense ARJ reflect empirically supported findings from original research that may be an analysis of new data collected by the authors or an analysis of primary sources (such as policy papers, program documents, interviews, memoranda, surveys, etc.). “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” (DAU, n.d.).
Another type of manuscript that Defense ARJ considers for publication is case histories. Note that case histories differ from case studies. Case studies are open-ended exercises, intended for pedagogical purposes, and used primarily in a classroom setting. Case histories, on the other hand, should provide a complete and focused analysis of the case and draw specific conclusions. They must be based on defense acquisition programs or efforts. They may be decision-based, descriptive, or explanatory. Defense ARJ considers case histories from all acquisition career fields and phases of the acquisition life cycle. Case histories submitted for consideration need to be authentic and factual. Each case history should clearly identify the situation/problem and its characters, provide detailed analysis, and draw conclusions. Currently, Defense ARJ publishes more original research articles than case histories, but the value of case histories should not be underestimated. A case history can be an excellent form of data collection, in which a particular research question can be considered in the context of real-life variables. Lessons learned from case histories can have far-reaching applications.

**Structure and Style**

Authors customarily develop articles from their thesis, dissertation, conference presentations, or reports. That said, journal article submitters should clearly understand that “there are—and should be—differences between papers that attract huge applause at the conferences, the best papers of the year selected by scientific journals and award-winning PhD theses” (Kekäle et al., 2009, p. 71). These differences are in length, of course, but also in structure, emphasis, and style. While a conference paper can certainly be developed into a successful manuscript for a research journal, it should undergo significant revisions in style, language use, emphasis, citations, etc. It will most likely need significant expansion; ideas will need clarification and explanation; theoretical background and methodology sections will require work as well. The same goes for a thesis. A researcher can likely produce more than one article for publication from a thesis or a dissertation of high quality. However, as a thesis is usually comprehensive regarding its topic, focus those articles on one or two issues/aspects, and narrow the scope of each. The same goes for workplace research and reports. Tailor them to the style of the research journal and show value to the larger readership of the journal. For instance, when the authors’ findings are narrow and applicable to their specific workplace, request that they reframe their paper in a way that would show the relevance of their work to the larger field, i.e.,
reframe their analysis “as an industry-wide recommendation” (Waks, 2005, p. 643). This is particularly true for case histories.

A research article begins with an introduction, followed by a clearly stated research question, a brief overview of relevant literature that grounds the author’s research, outlined methodology, description of instruments, discussion of results and limitations of the research, and its future implications. These parts are typical of any research article, although their headings may slightly differ. Tie all sections of the article together into a coherent narrative and support or explain the author’s argument. Gilmore et al. (2006) point out that “an ideal academic article should be a string of interrelated ideas that have a focus and are easy to follow” (p. 472).

Any article submission starts with an abstract and key words. Many authors find writing an abstract to be somewhat challenging. Compressing an article, one that the authors have likely spent significant time and effort fleshing out with vital details, into a few short sentences is not an easy task. The value of abstracts is too often underestimated; a strong abstract is absolutely vital. It serves as the primary point of engagement for prospective readers, acting as a short presentation of the article’s contents and value, at which point the reader often decides whether the article piques their attention and appears to be worth reading. A weak or unengaging abstract can just as easily drive readers away from otherwise useful information vs. a strong abstract that can pull them in. Therefore, the abstract is not a mere abridged version of the introduction; it contains some key statements about the paper, identifies the main argument as well as results of the study, its purpose and value, and its contributions and implications to the field. It should be carefully crafted and concise vs. a poorly written afterthought. Although the abstract is the first element in the article, it is best written after the manuscript is completed and polished, and all the details are finalized.
State the research question of the paper and its contribution to knowledge in the introduction. Authors may also briefly describe the background of the issue, but that can be done in a separate section. Kekälä et al. (2009) suggest that “the best use of the introductory chapter is to briefly—maybe on one page, at most—state the purpose and goal of the paper, maybe even to explain the logic of how the other chapters connect to each other in order to build a logical continuum (assuming they do)” (p. 72). The contribution of the paper is stated early in the manuscript. Demonstrate the relevance of your research to the journal readership, preferably in the opening paragraphs. That will help attract the reader’s attention, as well as allow the reviewers to assess the value of the manuscript. Suspense is not what reviewers are looking for when they have multitudes of submissions to review. Waks (2005) suggests that it is useful to restructure the submission:

as at least a partial answer to a question currently in the minds of your editor and his or her readers. To make this explicit, you must introduce your contribution by identifying this background question of current interest, and demonstrating, by appropriate citations, that this question is currently open and interesting. (p. 644)

“Many authors find writing an abstract to be somewhat challenging. Compressing an article, one that the authors have likely spent significant time and effort fleshing out with vital details, into a few short sentences is not an easy task.”

Within that context, the authors can then proceed to identify their narrow research question and explain how their work can help solve the larger background question. While authors will customarily include literature overviews in research papers and refer to theoretical thought, ensure that your paper is not based solely on theory and belief, and avoid the tendency to allot an excessive amount of space to reviewing other scholars’ work. Many beginning writers make the mistake of overciting, which then obscures their own contribution to the field. While familiarity with previous research is important, it is equally important to be deliberate in the prior literature you consider when constructing your manuscript. The overwhelming number of
resources your paper cites is unlikely to increase your realization of future publication. Since September 2018, the mean number of references in submissions rejected by Defense ARJ is nearly identical to that of accepted articles (both having a mean of about 27 references), while the median number is actually lower in accepted articles, 18 vs. 23. More is not always better; consider quality rather than quantity when constructing your research base: a smaller selection of deliberately chosen, well-considered references will likely be more beneficial than a reference section that is bloated with less useful or lower quality resources.

A research question can be defined as a problem the researcher sets out to solve, the raison d’être of the paper; in other words, why is this paper worth both writing and reading. Stating in your introduction that a particular problem has recently gained attention is not enough. That wording in and of itself does not explain the worth of the paper or the weight of the problem. A successful journal article will most likely focus on one research question, i.e., one problem that is well-researched and well-discussed. One may narrow down the question even further, for instance, by limiting it to a particular viewpoint. Such limitations are most often warranted by the word count journal articles are allowed. Brennan (2018) suggests that “your research questions/hypotheses should be operationalizable/measurable” (p. 694). Focus and express the research question in a clear manner.

Many beginning writers make the mistake of overciting, which then obscures their own contribution to the field. While familiarity with previous research is important, it is equally important to be deliberate in the prior literature you consider when constructing your manuscript.

More is not always better; consider quality rather than quantity when constructing your research base: a smaller selection of deliberately chosen, well-considered references will likely be more beneficial than a reference section that is bloated with less useful or lower quality resources.
Clearly define your research methodology. Ensure that your methods are appropriate for the research question and tie into the narrative of your research manuscript. Brennan (2018) insists that methodology needs to be able to “pass the replication/transparency test” (p. 694), which means that methods need be described with enough detail for other researchers to be able to recreate the study. Nevertheless, also remember that space is limited in a journal article, so conciseness is key. In addition, “data collection methods should be as neutral and unbiased as possible” (Brennan, 2018, p. 694), although this rule can be somewhat flexible when it comes to qualitative research. In such cases, allot some space to describing the research instruments such as interviews, program documentation, surveys, etc.

“A successful journal article will most likely focus on one research question, i.e., one problem that is well-researched and well-discussed.”

Results, their discussion, and implications should be the largest sections in the article. Kekäle et al. (2009) suggest that “journals exist solely to report findings, and so in a journal article the author must inevitably concentrate on them” (p. 75). Results need to be clearly described, and the “emphasis must … be on showing the reliability and validity of the research effort” (Kekäle et al., 2009, p. 75). Determine whether results are generalizable (in the case of Defense ARJ, whether they are generalizable for the larger defense acquisition community) and also discuss limitations of the study. “If appropriate, you could include concerns with methods, sample population, study power, sampling issue, uncontrollable variables, etc.” (Shidham et al., 2012, p. 6). Brennan (2018) advises to “find the unexpected in your research. If your results are obvious, your readers may feel cheated. Be able to explain your results in a convincing manner” (p. 694). It is always useful to come back to the “so what” question, the significance and relevance of the results. Cuervo-Cazurra et al. (2013) writes, “There are three types of articles in terms of importance. Some make one think after reading them, ‘I wish I had written this article.’ Others make one think, ‘I am happy that someone has written this article.’ And a third type makes one think, ‘I wonder why someone has written this article’” (p. 289). The editors are looking for papers that fit in with the first two categories of articles. Use the discussion section
to analyze your findings, point out which ones are most noteworthy, put them in the broader context of the field, justify your choice of methodology, and provide a short summary or conclusions based on your research (Shidham et al., 2012).

"Use the discussion section to analyze your findings, point out which ones are most noteworthy, put them in the broader context of the field, justify your choice of methodology, and provide a short summary or conclusions based on your research."

Manuscripts should be carefully edited, well proofread, easy to follow, and manifest an overall “polished” and professional submission. A submission that can be characterized as “polished” usually requires multiple drafts. Shidham et al. (2012) urge contributors to “rewrite-rewrite-rewrite” (p. 6). Read your manuscript with a brutal critical perspective and revise until it feels perfect. The editing focus will gradually shift from more global issues (such as extrapolating the original ideas, adding detail, working on the clarity of the argument and key statements) to adding transitions, editing sentence structure, word usage, punctuation, citations, etc. Defense ARJ recommends that authors not take an overly scholarly approach in either content or language. Make your manuscript easy to read and understand. Warren et al. (2021) point out that the main reason why certain articles make very little impact is lack of clarity in the writing and issues with “readability”: “Readers who are not already familiar with the research struggle to understand it. And when readers do not understand an article, they are unlikely to read it, much less cite it” (p. 42). Sharma (2018) provides great writing style advice:

"The connoisseur writer filters out unnecessary details and distills the essence of his/her communication in the manuscript. A short manuscript presented clear and lucidly is the most effective. Simple sentences in straightforward language convey the most information. A short sentence is easier to read and comprehend than a long rambling one, short, simple and familiar words are more reader-friendly than longer complicated phrases (replace ‘illustrate’ with ‘show’, ‘fundamental’ with ‘basic’ and ‘remainder’ with ‘rest’)." (p. 246)
Perform a grammar check and a spell check when all revisions are complete. Proper revisions and editing need time. It is often helpful to read the manuscript aloud to catch inconsistencies, or even take a step back from the article and possibly ask a colleague or your mentor to review your manuscript.

**Peer Review**

_Defense ARJ_ is a peer-reviewed research journal, which means that all submissions go through double-blind peer review to ensure impartial evaluation. The process of peer review in publication not only aims to enhance a particular field of study or research, but also seeks to help the researcher improve their writing skills and assist them in their professional development. Rejection rates are high for many journals in all fields of research. You cannot be afraid of rejections; everybody gets rejected. Brennan (2018) claims that “all top authors have experienced rejection. There is no shame in rejection. Some academics have even published their ‘CVs [curriculum vitaes] of failure’” (p. 698). This, however, does not necessarily mean that most of the submissions are of poor quality. It is not rare that submissions do not fit well with the emphasis and scope of a particular journal. They can be well-written and well-researched papers that simply do not correspond to the topics that a particular journal publishes. This is a crucial reason to carefully choose journals appropriate and best suitable for your work, to save both yourself, editors, and reviewers their valuable time.

> **Read your manuscript with a brutal critical perspective and revise until it feels perfect. The editing focus will gradually shift from more global issues (such as extrapolating the original ideas, adding detail, working on the clarity of the argument and key statements) to adding transitions, editing sentence structure, word usage, punctuation, citations, etc.**

When your manuscript receives a rejection, this does not mean it is the end of life for that particular paper. Approach rejection as a learning opportunity, carefully consider recommendations provided by the reviewers or the editors of the journal, revise your work, and resubmit. Sometimes it is best to resubmit to a different
venue, but occasions arise when journals accept extensively revised manuscripts that were previously rejected. Gilmore et al. (2006) also point out that “many studies have shown that the review process of academic articles is very imprecise and so a reviewer’s rejection may be faulty and the reviewer of another journal may accept the article” (p. 474). In other words, grow a thick skin and don’t allow yourself to become discouraged.

Approach rejection as a learning opportunity, carefully consider recommendations provided by the reviewers or the editors of the journal, revise your work, and resubmit.

Revisions are almost always required. It is very rare for a paper to get accepted with no revisions. So, “revise and resubmit” is a positive outcome, even though reviewers may be asking for extensive revisions, which means investing more time in the manuscript and most likely making significant changes to the text. It is easy to get frustrated with revisions, especially when the manuscript requires two or three rounds. However, you need to remember that, first, this situation is very common, and, second, the reviewers are not trying to sabotage your chances of getting published. Reviewers volunteer for a very time-consuming process to be able to better serve their field. Both editors and reviewers are looking for manuscripts with interesting new ideas that can contribute to the field and address new developments. Review their commentary as guidance and advice. “Reviewers give you their expertise free. They are trying to help you, though this may not always be apparent, especially if comments are expressed overly harshly” (Brennan, 2018, p. 698). You should approach revisions with a more positive attitude, as a chance to improve your work and writing skills and learn from the process. While making revisions, try to address as many reviewers’ suggestions as possible, especially paying attention to the larger issues. That said, knowledgeable, expert peer reviewers are not infallible. If a suggested revision seems to be off track and not possible to include in the paper, you should explain politely your viewpoint, backing up your position with proper
Always approach peer review with a positive outlook, and view revisions not merely as an unavoidable part of the process, but as a golden opportunity to grow and improve as a writer.

Conclusion

The publication process is an arduous one. From the slow, meticulous hours dedicated to research, to the exhaustive revision cycle needed to create an engaging manuscript, to the at-times brutal honesty of blind peer review, it is a significant commitment of both time and effort, which does not guarantee a satisfying conclusion. Yet, it is vital and worthwhile undertaking, both for the scientific community and for a researcher’s personal advancement.

In this analysis, we aimed to provide prospective authors with a number of strategies to help smooth the often-daunting prospect of peer review and publication. Researchers who are successful at publishing their findings aim to create novel research questions and use those to produce data that contribute to the conversation in their field. They are familiar with prior research in their field, look to build upon those foundations, but also let their own voice speak through their writing. Successful prospective authors also aim to create a piece that engages their
readers by leading with a strong research question and sticking to clear and concise writing. A clean, well-polished manuscript is more likely to receive positive attention from editors and peer reviewers. Authors who research the journal to which they plan to submit increase their likelihood of future publication. They also confirm that their manuscript aligns with the core subject matter of the publication and ensure that their submission closely follows the submission guidelines. Always approach peer review with a positive outlook, and view revisions not merely as an unavoidable part of the process, but as a golden opportunity to grow and improve as a writer.

With these tools, we hope and anticipate that prospective writers will be better equipped to share their research with the world, both in Defense ARJ and in the wider world of academic publications.
References


Author Biographies

**Dr. Olena McLaughlin**

is the interim managing editor of the *Defense Acquisition Research Journal*. From 2016 to 2019, she served as managing editor for *American Indian Quarterly*, a prominent research journal in Native American Studies. She holds a BA and an MA in Philology from Petro Mohyla Black Sea State University, Ukraine; an MA in Native American Studies from Montana State University; and a PhD in English from Oklahoma State University.

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**Christopher McGowan**

is the assistant editor of the *Defense Acquisition Research Journal*. In the past, he has served as a technical editor for the American Society of Health System Pharmacists. He holds BAs in Creative Writing and Computer Science from The University of Iowa.

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This Defense Industrial Base case history encourages critical analysis of a DoD project manager responding to typical management oversight questions regarding industrial base planning within defense acquisition. The analysis centers on the capability and capacity of the Defense Industrial Base to develop and produce body armor for Warfighters. The case incorporates the perspectives from key stakeholders to include commercial industry companies, congressional committees, DoD senior leadership, and the program management/acquisition chain of command. Considerations include the balancing of limited resources against competing priorities, sustaining inventory for wartime readiness, managing the demand for increased capability, and balancing surge requirements with industry capacity. The case history reinforces critical thinking in uncertain environments, documents lessons learned for sound project management, and provides exposure to the complexities of public sector acquisition and manufacture of critical warfighting products.

DOI: https://doi.org/10.22594/dau.23-905.31.01

Keywords: Defense Industrial Base planning, acquisition, inventory management, congressional oversight, Defense Production Act, industry competition, innovation
Defense acquisition professionals are routinely confronted with Defense Industrial Base (DIB) planning challenges, specifically program managers (PMs), as they formulate acquisition strategies for assigned programs. The DoD and its military services face DIB issues across the portfolio of products and services provided to Warfighters. Stakeholder identification and engagement remain critical to thoroughly study all options and consider second-order effects of distinct options. A difficult trade-off balance exists between the affordability of investing in a healthy and robust DIB for every Warfighter capability. At one end of the affordability spectrum is the importance of determining the minimum viable level to sustain production of Warfighter capability and support surge capability/capacity for contingency and emergency operations to maintain readiness. At the other end of the affordability spectrum is the importance of encouraging broad participation by commercial industry with companies of all sizes to compete and innovate, and push the technology envelope to produce better performing warfighter products and services. Limited budgets force the Services to accept risk in certain areas because of the ever-increasing demand for greater capabilities and the need to maintain a DIB capable of preserving national security interests. The balancing of these DIB priorities requires a thoughtful, data-driven approach to optimize limited resources.

Limited budgets force the Services to accept risk in certain areas because of the ever-increasing demand for greater capabilities and the need to maintain a DIB capable of preserving national security interests.

Background—Body Armor Situation

The U.S. Army Program Manager for Soldier Protection was contacted in May 2015 by the Program Executive Office Congressional Affairs Contact Officer (PEO CACO) and the PEO Public Affairs Officer (PEO PAO). Both stressed that there were issues and questions centered around the body armor plates that Soldiers fit into ballistic vests, which are designed to provide protection against fragmentation, pistol, and rifle threats. The PEO PAO was concerned about news media coverage, and the PEO CACO was relaying a warning order to be ready to support Army leadership as they prepared for congressional hearings on the Army’s portion of the President’s Budget
(PB) request, Fiscal Year (FY) 2016. Over the last year, the Army had responded to multiple congressional inquiries and Congress had recently directed the Army to spend more FY15 money on body armor. Despite these actions, the commercial companies that manufacture body armor had provided Congress and the media with an information paper painting an unacceptable situation with sustainment of a viable body armor DIB (Figure 1).

**FIGURE 1. U.S. HARD BODY ARMOR INDUSTRY IN CRISIS**

The Department of Defense (DoD) with the assistance of Congress has spent hundreds of millions of dollars to establish a world-leading industrial capability to design and manufacture state-of-the-art body armor plates. These plates, called Enhanced Small Arms Protective Inserts (E-SAPI), are bullet-stopping technology that has saved many lives in combat. At one point in 2007, the United States had seven major manufacturers of E-SAPI under contract and in sustainable production. Since that time, the industrial base has consolidated as requirements have increased and standards have been tightened to the point where there are only two viable manufacturers that can meet the current and potential future surge requirements for E-SAPI–BAE Systems & 3M-Ceradyne. These are the only remaining companies that can produce E-SAPI in an increasingly hostile battlefield environment. Both companies are on the verge of exiting the E-SAPI manufacturing business primarily due to decreased demand in DoD contracting and the lack of a DoD E-SAPI industrial base sustainment strategy. In the event of another major regional conflict, the potential is high for the U.S. Warfighters to be sent into battle with less than the best available body armor.

The key critical impact of losing the E-SAPI industry is that DoD loses the ability to surge manufacturing quickly in the event of a major regional conflict. These decisions (or lack thereof) will impact not only the primary E-SAPI manufacturers, they will affect an entire supply chain of companies that supply key component parts like ceramic tiles and high molecular weight polyethylene.

This has real impacts on critical manufacturing jobs in the U.S. These are skilled jobs that require training and precision. E-SAPI is not just another piece of gear. It is a highly engineered, precisely manufactured, lifesaving product. Every production run of E-SAPI is stringently and exhaustively tested in a destructive ballistic test that verifies and validates that each E-SAPI protects and functions to the most rigorous specifications. Very few items in the DoD inventory are routinely put through these types of tests.

If the DoD allows the E-SAPI industry to close down, it could have long-term impacts. This industry was not created overnight, and it will not be reestablished overnight. Americans who cannot be easily replaced will lose their jobs. Equipment will be sold off or mothballed. Entire segments of the supply chain may be forced to abandon their support and investment in E-SAPI.

*Note. Adapted from 3M Document to Congress (3M–Ceradyne, 2015).*
The U.S. Army for Soldier Protection PM examined the documents provided to Congress by body armor manufacturers and subsequently prepared information papers and slide presentations to address their concerns. The PM’s response was intended to educate Army senior leaders, congressional staff, and potentially congressional members on body armor plates. The timing of the manufacturers’ concerns to Congress jeopardized the planned Milestone C decision for approval from the Milestone Decision Authority (the PEO Soldier for this acquisition category III program) to award low-rate initial production contracts for next-generation armor plate protection. The PEO had already approved the acquisition strategy for the milestone review (U.S. Army, 2013a). The strategy included DIB planning as required by DoD acquisition regulations and guidelines (DoD, 2020a, 2022). The PEO requested to delay the planned milestone until after the Army addressed the manufacturers’ concerns that were shared with Congress. This request was intended to minimize any negative media coverage and update the strategy accordingly. A substantial change of the planned milestone would affect the acquisition program baseline’s cost and schedule and put the procurement funding at risk.

**Understanding Body Armor Procurement**

Over the prior two decades, the Army had improved the personal protective equipment (PPE) that Soldiers wore in battle. PPE against ballistics threats primarily included helmets, vests, and groin protection. Soldiers wore ballistic vests to protect the torso. Ballistic vests included layers of polymer (para-aramid or ultra-high molecular weight polyethylene [UHMWPE]) fibers woven into fabrics that provided protection against fragmentation and handgun threats (referred to as “soft armor”) (U.S. Army, 2013a). To protect against rifle threats, Soldiers inserted armor plates (referred to as “hard armor”) into pockets of their ballistic vests. The current Army vest was the Improved Outer Tactical Vest (IOTV), which accommodated four hard armor plates—identical front and back plates and two side plates (Figure 2). The Army had two versions of hard armor plates available, depending on the threat. The standard issue for each deploying Soldier was two enhanced small arms protective inserts (E-SAPI) and two enhanced side ballistic inserts (E-SBI) to be used with the IOTV (U.S. Army, 2014). The Army also had an inventory of X-threat small arms protective inserts (X-SAPI) and X-threat side ballistic inserts (X-SBI) that offered a higher level protection than E-SAPI and E-SBI (U.S. Army, 2014). The Army procured
hard armor plates with annual operation and maintenance (O&M) appropriations (i.e., one-year money) because plates were considered low-dollar items (despite also being classified as critical safety items) and using O&M dollars maintained budget flexibility (U.S. Army, 2013a). The average unit procurement cost (AUPC) for E-SAPI/X-SAPI was approximately $450, and the AUPC for E-SBI/X-SBI was approximately $250 (U.S. Army, 2014). The Defense Logistics Agency (DLA), which was the procurement activity for sustainment buys of hard armor, and the PM jointly maintained configuration control of the technical procurement specifications for hard armor plates and managed the qualification and acceptance testing of hard armor plate contracts. The legacy hard armor plate program was in the operations and support (O&S) phase of the acquisition life cycle—well past the procurement of the initial Army acquisition objective of 966,000 sets of plates (U.S. Army, 2014). For the procurement of expendable and worn out PPE, additional quantities of hard armor plates (beyond the Army acquisition objective) were required to replace the initially procured items.

As a result, Headquarters, Department of the Army (HQDA) G-4 worked with the Tank-automotive and Armaments Command Organizational Clothing and Individual Equipment Central Management Office (TACOM OCIE CMO) to annually program funding to replace hard armor plates. The two organizations jointly funded replacement of the plates using Sustaining Program Evaluation Group funding (jointly overseen by the HQDA G-4 and Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA[ALT])). The TACOM OCIE CMO procured Army PPE sustainment requirements through DLA Troop Support (TS) contracts.
Manufacturing Requirements

The Army embedded stringent requirements for its hard armor plates in manufacturing contracts using performance-based specifications, meaning the Army specified ballistics testing, interoperability, and interface requirements but did not specify the processes and materials (the “how”) contractors used to manufacture the plates. The use of performance-based specifications maximized competition, allowed for innovation, and protected each manufacturer’s intellectual property in terms of specific materials and manufacturing processes. Each manufacturer used varied materials and processes, but the hard armor plates all met the same performance requirements and were visually indistinguishable.

"The use of performance-based specifications maximized competition, allowed for innovation, and protected each manufacturer’s intellectual property in terms of specific materials and manufacturing processes."

Over time, in collaboration with researchers at the U.S. Army Research Laboratory and U.S. Army Natick Soldier Research, Development and Engineering Center, commercial industry had innovatively developed and manufactured higher performing hard armor plates. To meet the Army requirements/constraints for size, weight, and ballistic protection, industry vendors for the development and manufacture of hard armor plates discovered an optimal mix of materials and manufacturing processes. Hard armor plates protected the Soldier’s vital torso area, and maximum size dimensions were therefore limited. A trade-off existed between the weight of plates and the ballistic protection they provided. Heavier plates could potentially provide greater ballistic protection, but they also degraded mobility and increased battlefield fatigue. Commercial industry found that the best way to meet the performance requirements was to assemble a hard armor plate consisting of the following functioning layers:
• A core ceramic tile (made from either silicon carbide [SiC] or boron carbide [B₄C]) provides protection against ballistic threats and usually cracks when impacted by an incoming round (U.S. Army, 2015).

• Behind the ceramic plate is a crack arrester, a thin sheet of metal (like aluminum [Al] or titanium [Ti]) mesh that helps maintain the integrity of the ceramic tile if cracked when impacted by a threat round (U.S. Army, 2015).

• Behind the crack arrester are layers of polymer fibers (either made of para-aramid like Kevlar© or UHMWPE woven into thin sheets and then fused together (U.S. Army, 2015). These layers absorb any fragmentation that makes it through the ceramic tiles and any ceramic particles from cracked tiles.

• A cloth covering is fitted around all the layers so that plates appear visually indistinguishable.

To meet the Army requirements/constraints for size, weight, and ballistic protection, industry vendors for the development and manufacture of hard armor plates discovered an optimal mix of materials and manufacturing processes.

Commercial industry was given the freedom to innovate and use any combination of materials if the plates met the performance requirements (primarily ballistic protection, size, and weight). For example, X-SAPI and X-SBI were manufactured using SiC ceramic plates, but E-SAPI and E-SBI were manufactured with boron carbide B₄C ceramic plates (U.S. Army, 2015). The processes being used to manufacture the plates varied between commercial vendors (HQDA, 2015). The ceramic tiles were made from SiC and/or B₄C powder, which is put under heat and pressure for a period to form a ceramic tile with the desired properties (HQDA, 2015). Different processes (sintering or hot pressing) result in different ceramic properties, resulting in varying levels of ballistic protection (HQDA, 2016). The bottom line is that the hard armor plates were highly engineered, as certified by commercial industry in Figure 1, with an optimized design to meet the stringent Army performance requirements.
In May 2013, the Army approved and funded the Soldier Protection System (SPS) program of record with a Milestone B approval to award engineering and manufacturing development (EMD) contracts (U.S. Army, 2013b). The SPS was the first Army PPE program that simultaneously integrated development of the five distinct parts of the PPE ensemble. SPS was to provide Soldiers with an integrated, scalable, tailorable PPE ensemble with a protection level equal to or greater than current levels and at a lighter weight (U.S. Army, 2013a). Figure 3 provides an overview of the SPS components.

**FIGURE 3. SOLDIER PROTECTION SYSTEM OVERVIEW**

Soldier Protection System (SPS) replaces the capability of multiple current systems and provides Soldiers a 10% weight reduction—reducing soldier load!

*Note.* Adapted from U.S. Army PowerPoint briefing to Army senior leaders (U.S. Army, 2013a).
The newer hard armor plates of SPS were named vital torso protection (VTP; U.S. Army, 2013). The Army-approved capabilities development document contained only one key performance parameter for the VTP: provide an equivalent ballistic level of protection as current E-SAPI/E-SBI/X-SAPI/X-SBI at 10% lighter weights (Figure 4; U.S. Army, 2013b).

Two companies, 3M (owned by Ceradyne) and BAE Systems, were awarded EMD contracts for VTP hard armor in September 2013 (U.S. Army, 2015). The EMD contracts had firm fixed price contract options to develop and deliver VTP plates for ballistic testing (U.S. Army, 2015). The competing vendors delivered plates for two rounds of first article testing (U.S. Army, 2013a). After successfully passing ballistic testing, the SPS VTP program prepared for a Milestone C, low-rate initial production (LRIP) option.

![FIGURE 4. SOLDIER PROTECTION SYSTEM VITAL TORSO PROTECTION DESCRIPTION](image)

*Note.* Adapted from Powerpoint briefing to Army leadership (U.S. Army, 2013a). The five sizes of plates are extra small, small, medium, large, and extra large; side plates only come in one size.
contract award, planned for July 2015 (U.S. Army, 2013b). The program office shared the results of the development program with the Army requirements community (HQDA G-3/5/7 and U.S. Army Training and Doctrine Command). HQDA G-3/5/7, after reviewing approved requirements documents, determined that the Army acquisition objective to be 266,000 sets of plates (U.S. Army, 2013b). Procurement of the SPS (including VTP plates) was planned, programmed, and budgeted with O&M dollars in the Army Equipping Program Evaluation Group, which was overseen by the HQDA G-3/5/7 and ASA(ALT). The SPS procurement funding was placed in the program element managed by the PM, who collaborated with the Army Contracting Command to award the procurement contracts. Figure 5 presents the competitors’ EMD results achieved with VTP plates. As a result of what was learned to be technically

![Figure 5. SPS VTP Development Testing Summary](image)

- Average E variant weight reduction: 9.5% reduction in weight over legacy E-SAPI/E-SBI or 1.4 lbs reduction per set
- Average X variant weight reduction: 11% reduction in weight over legacy X-SAPI/X-SBI or 1.98 lbs reduction per set

**Note.** Adapted from PowerPoint briefing to Army leadership (U.S. Army, 2015). B\(_2\)C = boron carbide; E-SAPI = enhanced small arms protective insert; E-SBI = enhanced side ballistic insert; SiC = silicon carbide; X-SBI = X-threat side ballistic insert; X-SAPI = X-threat small arms protective insert.
feasible and manufacturable during the EMD phase, HQDA G-3/5/7 modified the requirements in the VTP capability production document (CPD) to achieve the ballistic protection of current hard plates with a weight threshold of 7% less and an objective weight reduction of 30% less than current plates (U.S. Army, 2015). The AUPC for the VTP (E-SAPI/X-SAPI) was approximately $700, and the AUPC for the VTP (E-SBI/X-SBI) was approximately $450 (U.S. Army, 2015). For this acquisition effort, the big “A” acquisition system worked as intended in that the results of the EMD phase were used to update the formal production requirements document from the Joint Capabilities Integration and Development System. The Army also prioritized appropriate resources in the planning, programming, budgeting, and execution (PPBE) system for the procurement of the SPS VTP plates.

“For this acquisition effort, the big “A” acquisition system worked as intended in that the results of the EMD phase were used to update the formal production requirements document from the Joint Capabilities Integration and Development System.

Resourcing Constraints and Congressional Involvement

As part of the PPBE system, the DoD annually prepares the FY budget, called the budget estimate submission, which transitions into the PB request submitted to Congress for review each year in February (Rendon & Snider, 2019). The FY16 PB was submitted to Congress in February 2015. Following submission of the PB, congressional hearings were scheduled to help Congress understand the PB and subsequently draft legislation—specifically the annual National Defense Authorization Act (NDAA) and the annual Appropriations Act. The NDAA authorizes programs and policies, while the Appropriations Act provides the DoD with permission to obligate dollars (Rendon & Snider, 2019). The DoD cannot spend government money on programs without those programs first being authorized in an NDAA and subsequently funded in the Appropriations Act (Rendon & Snider, 2019).
The House Armed Services Committee (HASC) and the Senate Armed Services Committee (SASC) are responsible for writing the annual NDAA (Rendon & Snider, 2019). The House Appropriations Committee (HAC) and Senate Appropriations Committee (SAC) write the annual Appropriations Act (Rendon & Snider, 2019). Regarding defense body armor, SASC/HASC/SAC/HAC professional staff members reached out to the Army with questions and potential issues with the body armor plate DIB and associated requested funding levels in the FY16 PB request.

An area of emphasis for HASC/SASC/HAC/SAC was the health of the DIB in times of limited budgets and declining resources. Of particular interest to the committees was the health of the body armor DIB, especially the hard armor plates worn by Soldiers and Marines in their ballistic vests. Congress had repeatedly asked for information regarding the health of the body armor DIB. The FY13 NDAA HASC report “directed the Secretary of the Army to provide a briefing to the congressional committees that provides an assessment of the long-term sustainment requirements for the body armor industrial base in the United States, to include supply chains for both hard and soft armor” (H.R. Rep. No. 112-479, 2012, p. 59). The next year, section 253 of the FY14 NDAA required “the Secretary of Defense to provide a report on the comprehensive Research and Development strategy of the Army Secretary to achieve significant reductions in the weight of body armor” (NDAA, 2013, p. 127). Finally, the FY15 NDAA Senate report required the Secretary of the Army to conduct a “technical study and business case analysis on the requirements, cost, benefit, feasibility, and advisability of the replacement and refurbishment of the various body armor plates used in personal protective equipment” (S. Rep. No. 113-176, 2014, p. 33).

**Hard Armor DIB Planning**

DoD acquisition directives and regulations require DIB planning for all acquisition programs of record (DoD, 2012, 2022). (The appendix to this article details PM responsibilities for DIB planning guidance in DoD Instructions and the organization of the DoD overseeing DIB policy, Defense Production Act of 1950 implications, and diminishing manufacturing sources and material shortages (DMSMS) management policies. The authorities of the Defense Production Act of 1950 allow the DoD to incentivize commercial industry to enter contracts with the DoD and place “ratings” on the contracts (DoD, 2012). Work on “rated” contracts is prioritized over “nonrated” contracts (DoD, 2012). The procurement contracts of legacy hard armor and the SPS VTP development contracts were rated as “DO” contracts, meaning that vendors
were required to prioritize these efforts over “nonrated” efforts (U.S. Army, 2013a). DoD general policy for DIB planning is that the DoD does not preserve the DIB capacity/capability unless national security requirements are at risk and retaining it is cost-effective (DoD, 2012).

In response to the requirement from the FY13 and FY14 NDAAs, the Army prepared a report for Congress entitled Secretary of the Army’s Response to Congressional Defense Committees on Body Armor Research and Development and Sustainment Strategies (HQDA, 2014). The report provided a status of current PPE systems, an overview of research and development efforts to improve protection and reduce Soldier load (weight), and a PPE DIB assessment. The Army’s goal was to maintain at least two vendors to maintain competition and promote innovation. With respect to hard armor plates, the Army acknowledged two vendors, BAE Systems and 3M–Ceradyne, as producing current plates through DLA contracts (HQDA, 2014). These same two vendors were awarded SPS VTP development contracts for lighter weight hard armor plates (U.S. Army, 2015). The HQDA G–4 highlighted that current inventory of hard armor plates met contingency and training requirements in the near term (HQDA, 2014). In this same report, DLA stated the short-term risk assessment (FY14 and FY15) for hard armor DIB as significant due to a considerable drop in demand and vendors operating below their stated minimum sustaining rates (MSRs; HQDA, 2014). DLA assessed the long-term risk (FY16 and beyond) as significant due to a low demand, dependence on the DoD, and an 18-month estimate to reconstitute the capability if vendors stopped production (HQDA, 2014).

The Army Program Management Office updated its hard armor DIB assessment in June 2014, concluding that the current planned funding levels for sustainment buys of legacy E–SAPI/X–SAPI and E–BSI/X–SBI, combined with planned SPS procurements of VTP E–SAPI/X–SAPI and VTP E–SBI/X–SBI, would fall below the funding levels required for the MSRs of the commercial vendors (U.S. Army 2014). 3M–Ceradyne stated that its MSR of production was 12,000 plates per month, and BAE’s MSR was 10,000 plates per month (U.S. Army, 2014). The Army inspected about 550,000 hard armor plates per year with nondestructive test equipment (NDTE), using X-ray technologies to check for ceramic cracking and delamination issues from 2008 through 2014 (U.S. Army, 2014). Based on the failure rate (or washout rate) of the total inspected plates per year, the service life of E–SAPI and X–SAPI was estimated to be 10 years, and the service life of the E–SBI and X–SBI was estimated between 34 and 69 years (U.S. Army,
In 2014, the DoD sponsored the following reports to assist in the body armor DIB planning:

- In September 2014, the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, Manufacturing and Industrial Base Policy (OUSD[AT&L/MIBP]) published a study of the hard armor industry by the RAND Corporation as part of the comprehensive sector-by-sector, tier-by-tier (S2T2) analysis (DoD, 2014). In February 2015, the RAND Corporation completed a comprehensive assessment of the PPE on behalf of the OUSD(AT&L) (Younossi et al., 2015).

The S2T2 is a standardized industrial base analysis approach and methodology for assessing the health of the DIB with the following objectives (DoD, 2014):

- Establish early warning indicators and identify DIB risk.
- Analyze the effect of DoD portfolio decisions on the DIB.
- Analyze single points of failure, unreliable suppliers, overreliance on foreign sourcing, and areas of limited competition, particularly at the lower tiers of the supply chain.
- Define plans and strategies for mitigating identified DIB risks.
- Support long-term planning and investment decisions by and across the Services (DoD, 2014).

The S2T2 process assessed the fragility (characteristics that make a specific capability likely to be disrupted) and criticality (characteristics that make a specific capability difficult to replace if disrupted with a capability defined as either a technology, part, component, or product; DoD, 2014). The hard armor industry supply chain included hard body armor (systems integration) manufacturers, ceramic tiles producers, SiC/B\textsubscript{4}C ceramic powder facilities, UHMWPE and aramid fibers manufacturers, and fabric weavers (DoD, 2014). One important consideration from the S2T2 analysis that complicated DIB planning was that the manufacturers had different business operating models (U.S. Army, 2014). 3M–Ceradyne operated with
a vertically integrated business model—meaning that the company owned and operated a mine for the raw ceramic powder, a ceramic tile manufacturer, and a hard armor plate integration and assembly plant, all in various locations (DoD, 2014). BAE Systems, on the other hand, operated with a horizontally integrated business model, meaning that the company procured ceramic tiles from the commercial market and then owned and operated the hard armor plate integration and assembly plant at a specific location (DoD, 2014).

As directed in Public Law 113–66, the FY14 NDAA, the OUSD(AT&L) provided Congress with the Department of Defense Report to Congress on Personal Protection Equipment in February 2015 (DoD, 2015). This report built upon the conclusions of the previously referenced studies. With respect to DIB concerns, the report listed the following risk mitigation steps being considered: “the use of Industrial Base Maintenance Contracts, stockpiling, changes in procurement strategies, and qualification of domestic suppliers” (DoD, 2015, p. 14). More generally, “Opportunities to rely on commercial markets, demand for defense-unique products, cooperative international developments and foreign sources, and adequate transfer of technology are key factors to sustaining a healthy industrial base capable of responding to future requirements” (DoD, 2015, p. 14). The report continues:

Funding available for initial procurement of SPS during the FY2016–2020 timeframe will likely be at or potentially even below most producers’ Minimum Sustaining Rates of production. Therefore, as soon as it is practicable after SPS subsystems have entered FRP [full rate production], the Army should consider ceasing the sustainment of older versions of body armor and helmets and apply its sustainment funds toward procuring SPS variants of body armor and helmets. This “Modernization through Sustainment” strategy would help to ensure that the Army is modernizing its stockpile of PPE assets, even as it begins initial procurement of the SPS. In addition, and equally as important, using sustainment funds to procure the latest systems will help the Army to maintain and support the most current and capable production base. (p. 21)

In response to the FY15 NDAA, the Army completed a report to Congress entitled Technical Study and Business Case Analysis of Body Armor Plates in February 2015
The service life of current hard plates was determined by the Army and presented in Table 1. The Army’s PEO Soldier calculated the estimated service life from the annual washout rate of currently fielded hard body armor. The washout rate was based on the total number of plates that failed inspection, divided by the total number of plates inspected during the years 2008 to 2014 (HQDA, 2015).

### TABLE 1. HARD ARMOR SERVICE LIFE AND WASHOUT RATES

<table>
<thead>
<tr>
<th>Material</th>
<th>Expected Service Life (Years)</th>
<th>Annual Washout Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-SAPI</td>
<td>10.3</td>
<td>6.48%</td>
</tr>
<tr>
<td>E-SBI</td>
<td>42.2</td>
<td>1.63%</td>
</tr>
<tr>
<td>X-SAPI</td>
<td>17.6</td>
<td>3.86%</td>
</tr>
<tr>
<td>X-SBI</td>
<td>85.2</td>
<td>0.81%</td>
</tr>
</tbody>
</table>

**Note.** Adapted from technical study and business case analysis (HQDA, 2015). E-SAPI = Enhanced Small Arms Protective Insert; E-SBI = enhanced side ballistic; X-SAPI = X-threat small arms protective insert; X-SBI = X-threat side ballistic insert.
TABLE 2. HARD ARMOR PLATE COMPARISON

<table>
<thead>
<tr>
<th></th>
<th>MATERIAL</th>
<th>WEIGHT (EACH)</th>
<th>COST (EACH)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LEGACY E–SAPI</strong></td>
<td><strong>BORON CARBIDE (B, C)</strong></td>
<td>5.45 LBS</td>
<td>$472</td>
</tr>
<tr>
<td><strong>LEGACY X–SAPI</strong></td>
<td><strong>SILICON CARBIDE (sic)</strong></td>
<td>6.00 LBS</td>
<td>$450</td>
</tr>
<tr>
<td><strong>VTP E–SAPI</strong></td>
<td><strong>BORON CARBIDE &amp; SILICON CARBIDE</strong></td>
<td>5.07 LBS</td>
<td>$719</td>
</tr>
<tr>
<td><strong>VTP X–SAPI</strong></td>
<td><strong>SILICON CARBIDE</strong></td>
<td>5.58 LBS</td>
<td>$708</td>
</tr>
</tbody>
</table>

Note. Adapted from technical study and business case analysis (HQDA, 2015). E–SAPI = Enhanced Small Arms Protective Insert; E–SBI = enhanced side ballistic; VTP = vertical torso protection; X–SAPI = X-threat small arms protective insert; X–SBI = X-threat side ballistic insert.

The PEO’s methodology and results were validated by the Army Materiel Systems Analysis Activity and were based on hard armor surveillance testing data collected from nondestructive test equipment (U.S. Army, 2014). The Army maintained a stockpile of 147,000 sets of X–SAPI and 150,000 sets of X–SBI for future contingencies (HQDA, 2015). Based on the status of the current stockpile, the Army had no plans to procure any additional E–SAPI or E–SBI plates with sustainment funding after current deliveries under DLA TS contracts completed (HQDA, 2015). The Army planned to begin LRIP of lighter weight plates under the SPS program beginning in 4QFY15 (U.S. Army, 2013). The number of complete sets of SPS hard body armor to be produced per year in FRP was estimated to be 20,760 per year beginning in FY16, equating to 41,520 E–SAPI and E–SBI plates, and 41,520 X–SAPI and X–SBI plates (HQDA, 2015).
For purposes of comparison to stated industry MSR of production, the planned production rates amounted to 5–10 months of production per year for one producer (HQDA, 2015). In a supplemental authorization to the FY15 NDAA, an additional $80 million in funding authorization was included for the body armor DIB (HQDA, 2015). The Army intended to use the $80 million to procure the lighter weight SPS VTP E-SAPI and E-SBI, and X-SAPI and X-SBI plates for production in FY16 in lieu of procuring legacy plates (HQDA, 2015). Table 2 quantifies the discriminating differences between legacy plates and SPS VTP plates. The supplemental funding would procure a minimum of 35,320 complete sets of lighter body armor (front, back, and side plates), utilizing SPS VTP existing contracts (HQDA, 2015).

**Analysis of DIB Planning and Decision Making**

The PM considered the wealth of information that existed with respect to the hard armor DIB planning over the last few years and formulated a list of questions to prepare senior Army leaders for congressional hearings regarding the body armor DIB and the concerns raised by commercial industry.

**Who were the stakeholders for the hard armor DIB?**

Stakeholder identification and engagement were critical in effectively dealing with issues and challenges in the hard armor competitive landscape. The following were considered the key stakeholders:

- **Soldier/Warfighters:** Concerned about performance as the customer and user of the hard armor plates. Interestingly, they were not a key stakeholder in the decision-making process, but Warfighter interests were critical in approving requirements and funding.
- **Army senior leaders:** Concerned about providing Warfighters the best PPE, maintaining a healthy DIB, and maintaining affordability within budget constraints.
- **Congress:** Concerned about providing Warfighters the best PPE, and maintaining a healthy and competitive DIB. Also, Congress was getting pressure from specific companies in specific congressional districts about the decreasing demand for hard armor plates.
- **Industry:** Concerned about maintaining their minimum sustaining rates for manufacturing hard armor plates.
Program Manager: Concerned about DIB planning and maintaining the acquisition program baseline of cost, schedule, and performance to support the Warfighter.

Understanding the concerns of the stakeholders allowed Army senior leaders to consider options addressing these concerns, enabling a decision-making process that was more inquiry-based than advocacy-based when comparing options.

**What were the DoD/Army and industries’ assessments of the hard armor DIB, and why did they differ?**

Commercial industry’s and the DoD/Army’s assessment of the hard armor DIB differed because they viewed the same data from different perspectives. Both industry and the DoD acknowledged that a decreasing demand signal for future buys of hard armor plates had created limited competition within this sector. Both were also concerned that future planned procurements fell below the minimum sustaining rates of production, resulting in exits from the sector of competitors, plant shutdowns, layoffs, and the loss of DIB capability and capacity (3M-Ceradyne, 2015; HQDA, 2015). It would take approximately 18 months to restore this capability and capacity if lost completely (U.S. Army, 2014). How to handle this challenge was where the DoD and industry had differing opinions. Industry wanted to produce more legacy plates to avoid these challenges. They knew how to produce high-quality, legacy plates. Industry was less enthusiastic about the next generation, lighter weight SPS plates because they could not be guaranteed orders for all the types of new plates. Each company successfully demonstrated manufacturing only a subset of the plates to the new requirements, thereby limiting potential future orders (better to make all versions of the legacy plates than be limited to certain versions of the next generation plates). However, the Army tracked the inventory of plates in stockpiles as well as the current washout rates of plates and determined that enough legacy plates existed in stockpiles to meet future Warfighter demand requirements (HQDA, 2015). The bottom line was that armor plates had long service lives and even longer shelf lives, which was a good situation for the DoD—the plates lasted a long time. The Army decided that any planned resources would be prioritized toward buying the next generation lighter weight plates rather than buying more legacy plates (HQDA, 2015).
How many vendors should be preserved to maintain the DIB?

The question of how many vendors constituted a healthy DIB was also a key consideration. For competition and innovation reasons, more vendors were better for a healthy DIB. Maintaining more vendors came at an increased cost in terms of configuration control of plates and greater fixed costs for multiple production facilities. Additionally, the two remaining competing vendors for hard armor plates had drastically different business models—vertically versus horizontally integrated (DoD, 2014). The fixed costs for the vertically integrated company (includes the raw material manufacturer, tile maker, and plate integrator) was much larger than the fixed costs for a horizontally integrated company (e.g., just a tile integrator who procured tiles on the commercial marketplace). Therefore, the Army was comfortable with maintaining only two viable hard armor plate manufacturers.

What options should the Army consider?

Specifically, should the Army buy SPS plates or legacy plates and how many? Based on the documented analyses, reports, constraints, and stakeholder analysis, the PM team presented the following options to Army leadership for consideration:

- **Option 1: Buy SPS plates to approved Acquisition Objective (AO).** In this option, the Army buys the next generation SPS VTP plates at the planned, programmed, and budgeted level in the approved program objective memorandum.
- **Option 2: Fund MSR of SPS plates.** In this option, the Army increases planned funding to buy SPS VTP plates at the MSRs of the competing vendors.
- **Option 3: Buy and stockpile legacy plates.** In this option, the Army uses the planned money for SPS VTP plates and instead buys legacy plates.
- **Option 4: Fund MSR of legacy plates.** In this option, the Army increases planned funding to buy legacy plates at the MSRs of the competing vendors.
- **Option 5: Fund IBMCs.** In this option, the Army negotiates contracts with vendors to fund what the vendors describe as their fixed costs to manufacture plates. The Army would not actually buy plates but would dramatically decrease the reconstitution time if a vendor did not get orders for plates and had to mothball the production facility.
• **Option 6: Encourage Foreign Military Sales (FMS) of legacy plates.** In this option, the Army works with the State Department to authorize the sale of armor plates to U.S. allies.

To fairly compare the options, the PM team defined decision criteria. The PM team considered the programmatic triple constraint of cost, schedule, and performance as well as DIB considerations as appropriate criteria. Decision criteria consisted of the following:

- **Cost:**
  - Total Life Cycle Costs (TLCC): Defined as all the costs associated with an option, and lower was better.
  - AUPC: Defined as the plate per unit cost, and lower was better.
- **Performance (P):**
  - Ballistic protection: Defined as protection afforded by the plates. The next generation SPS plates and legacy plates provided equivalent ballistic protection; therefore, ballistic protection was a nondiscriminating criterion.
  - Plate weight: Defined as the weight of each armor plate, and lighter weight plates were better.
- **DIB:**
  - Capability: Defined as the ability (the “know-how”) to manufacture quality plates, and more “know-how” was better.
  - Capacity: Defined as the volume of plates that can be manufactured, and greater capacity was better.
  - DMSMS and obsolescence: Defined as mitigating the risks associated with obsolescence, manufacturing shortages, and material shortages in the body armor supply chain.

What were the advantages and disadvantages of distinct options to preserve the hard armor DIB? The PM team completed a first-level analysis by comparing the options against the defined criteria by listing the advantages and disadvantages of
### TABLE 3. ADVANTAGES AND DISADVANTAGES OF OPTIONS

<table>
<thead>
<tr>
<th>Option</th>
<th>+ ADVANTAGES</th>
<th>- DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Buy SPS Plates to AO</td>
<td>Performance, DIB (Capability, Capacity, DMSMS, Obsolescence)</td>
<td>Cost (TLCC, AUPC)</td>
</tr>
<tr>
<td>2. Fund MSR of SPS Plates</td>
<td>Performance, DIB (Capability, Capacity, DMSMS, Obsolescence)</td>
<td>Cost (TLCC, AUPC)</td>
</tr>
<tr>
<td>3. Stockpile Legacy Plates</td>
<td>Cost (AUPC), DIB (Capability, DMSMS)</td>
<td>Performance, Cost (TLCC), DIB (Capability, Obsolescence)</td>
</tr>
<tr>
<td>4. Fund MSR of Legacy Plates</td>
<td>Cost (AUPC), DIB (Capability, DMSMS)</td>
<td>Performance, Cost (TLCC), DIB (Capability, Obsolescence)</td>
</tr>
<tr>
<td>5. Fund IBMC</td>
<td>Cost (TLCC and AUPC)</td>
<td>Performance, DIB (Capability, Capacity, DMSMS, Obsolescence)</td>
</tr>
<tr>
<td>6. FMS Legacy Plates</td>
<td>Cost (TLCC and AUPC), DIB (Capability, DMSMS)</td>
<td>Performance, DIB (Capability, Obsolescence)</td>
</tr>
</tbody>
</table>

**Note.** AO = acquisition objective; AUPC = average unit procurement cost; DMSMS = diminishing manufacturing sources and material shortages; FMS = Foreign Military Sales; DIB = Defense Industrial Base; IBMC = Industrial Base Maintenance Contract; MSR = minimum sustaining rate; SiC = silicon carbide; SPS = Soldier Protection System; TLCC = Total Life Cycle Costs.
each option (Table 3). This comparison of criterion as an advantage or disadvantage for each option proved insightful. The performance criterion (lighter weight plates) was important, and options 1 and 2 provided the Warfighter with lighter weight plates. Performance was a disadvantage for the other options because those options provided the Warfighter with legacy plates. Each of 4 DIB subcriteria were used to compare options as well. Options 1 and 2 had the advantage of capability, capacity, DMSMS, and obsolescence. Options 3, 5, and 6 had advantages in capacity and DMSMS, but disadvantages in capability and obsolescence. Option 5 did not preserve the DIB for capability, capacity, DMSMS, and obsolescence. This type of comparison proved difficult for decision making because it did not articulate the relative ranking of each option for each criterion. For example, the TLCC cost was a disadvantage for options 1 and 2 compared to the TLCC of other options, but option 2 had a higher TLCC than option 1. Similarly, TLCC had an advantage for options 5 and 6 compared to other options, but the TLCC of option 6 was lower than the TLCC of option 5.

The PM team used a decision matrix to overcome the weaknesses of simply listing pros and cons of options. Each of the six options was qualitatively ranked in all the criteria. The decision matrix helped Army senior leaders understand the options better. A sensitivity analysis was used to more accurately account for some criteria being more important than other criteria. The TLCC cost criterion was considered twice as important as the AUPC cost criterion. Additionally, the performance criterion was considered twice as important as the four DIB criteria combined. With weighted criteria, a greater separation of option ranking scores was achieved, with option 1 and option 2 scoring better than options 3, 4, 5, and 6. This made sense because options 1 and 2 involved the manufacture of next generation, lighter weight plates with some DIB preservation advantages. Also, because the TLCC cost criterion was twice as important as AUPC cost criterion, one would expect option 1 to be slightly preferred over option 2, which had considerable affordability concerns to fund two vendors at their MSRs for SPS VTP plates. When comparing the lower cost options (5 and 6), it was also apparent that encouraging the FMS of legacy plates was preferred because it was the lowest cost option for the Army while still having some DIB preservation benefits.

While the decision matrix provided more information than the comparison matrix presented in Table 3, a cost–benefit analysis offered an alternative way to analyze options. However, being able to quantify and monetize the benefits proved difficult.
More reasonable was a cost-effectiveness analysis where measures of effectiveness (MOE) were defined, and the MOEs were compared to costs of the options. The defined decision criteria (except cost criteria) were used as MOEs. The most important MOE for hard armor plate was ballistic protection. For the legacy and new hard armor plates, the ballistic protection of the plates was to be maintained at the same level, making ballistic protection a nondiscriminating MOE. The next MOE for plates was weight reduction. The newer SPS VTP plates weighed less than the legacy plates. The qualitative benefits associated with lower weight plates included increased battlefield mobility, less battle fatigue, lower combat injuries, increased readiness, lower long-term health effects, and lower long-term Veterans Administration health care demands. The final MOE was DIB preservation in terms of capability, capacity, DMSMS, and obsolescence. Just as in the decision matrix analysis, performance (weight reduction) was twice as important as the four IP criteria combined. The cost effectiveness analysis, the MOE scores for each option were normalized with the highest scoring option, as 100% effective and the other options plotted proportionally less than 100% effective against the options TLCC. Option 2 had the highest MOE but also the highest overall costs. Option 1 was less effective than option 2 with lower overall costs because option 1 only funded the vendors to produce the acquisition objective required quantities, which was less than their MSRs. There was a significant drop-off in effectiveness between options 2 and 1 and options 3–6. The legacy plates weighed 6.00–5.45 pounds at $450–472 each, whereas the SPS VTP plates weighed 5.58–5.07 pounds at $718–798 each (Table 2). For each Warfighter, a 7% decrease in combat weight had a 52–57% increase in costs. To procure the acquisition objective of 266,000 sets of plates, the Army would spend $245.3 million for legacy plates compared to $379.6 million for new lighter weight plates. This equates to a $134.3 million decision for a weight reduction of 0.74–0.84 pounds per Warfighter.

As presented in Figure 1, industry was pressuring Congress to force the Army to fund the competing vendors to manufacture legacy plates at their MSRs (option 4). However, option 1 (procuring SPS plates to Warfighter requirement) dominated option 4, meaning that option 1 had a higher MOE at a lower cost; therefore, the Army favored option 1 over option 4. In the fragility and criticality (FAC) analysis as part of the S2T2 study of the hard armor plate DIB, Industrial Base Management Contracts (IBMCs) were recommended (DoD, 2014). But the FMS of legacy plates (option 6) dominated the IBMC (option 5), meaning that the FMS option provided the Army greater MOE for a lower cost. Additionally, the IBMC option presented considerable implementation challenges. Because each of the vendors had different business
models, the issue of competitive fairness between the funding of fixed costs of different business models remained. The question also remained as to whether the Army or DLA had the responsibility to fund the IBMCs. Finally, if the vendors’ fixed costs were covered by an IBMC, then future plate unit prices would be lower (only covering for variable costs)—a consequence that concerned industry vendors. The bottom line was that IBMCs sounded reasonable, but the Army and DLA determined that too many challenges existed to fairly consider awarding IBMCs.

The recommendations allowed flexibility for the Army to address the hard armor DIB challenges while balancing against other DIB preservation priorities. The recommendations also did not “tie the hands” of Congress or put Congress in the position of arbitrarily picking winners or losers.

A marginal benefit to marginal cost comparison proved useful to compare the remaining viable options (options 1, 2, 3, and 6). Option 3 (buy and stockpile legacy plates) had a small benefit over option 6 (FMS sales of legacy plates) but at a higher cost. The Army determined that the marginal benefit of option 3 was not worth the marginal cost. Option 2 (fund the SPS plates at the MSRs) had a higher MOE than options 1 and 6 at the higher cost. Affordability constraints severely limited the viability of option 2. With limited budgets and difficulty of balancing the preservation of DIB across different sectors, funding the MSRs of vendors in the hard armor plates was not as high a priority for the Army as other areas of the DIB. Last was the comparison between option 1 (buy SPS to the requirement) and option 6 (FMS sales of legacy plates). Army senior leaders determined that option 1 was worth the additional cost because it provided improved capability to the Warfighter, whereas option 6 had only DIB preservation benefits and provided no additional capability. In the end, the PM team recommended a combination of option 1 and option 6 to Army senior leaders. The complete DIB analysis supported the Army in congressional hearings, enabling senior leaders to answer questions from both the authorization and appropriations committees.
Conclusions

This DIB case history demonstrated the complexity of the defense acquisition environment and decision-making process involved in planning the preservation of a competitive market in providing unique military capabilities. The hard armor DIB was one of hundreds of highly specialized manufacturing facilities. In a resource-constrained environment, the optimization of spreading limited funding across multiple sectors and within multiple tiers of the supply chain was challenging but required to limit national security risks. Even for a military product as seemingly simple as hard armor plates compared to major platforms like aircraft, combat vehicles, or ships, this case illustrated a complex stakeholder environment. A better understanding of stakeholder concerns enabled a better informed analysis. The perspectives of Congress, industry partners, senior leaders, and Warfighters allowed for the analysis of distinct options against the criteria of performance, cost, and DIB preservation considerations like capacity, capability, obsolescence, and DMSMS. Comparison tables, decision matrices, and cost effectiveness studies enabled a progressively more sophisticated analysis to make better recommendations to senior decision makers for a more informed decision process.

In the end, recommendations to congressional committees about potential NDAA language or potential marks to the PB request satisfied the Army, the DoD, industry, and Congress. The recommendations allowed flexibility for the Army to address the hard armor DIB challenges while balancing against other DIB preservation priorities. The recommendations also did not “tie the hands” of Congress or put Congress in the position of arbitrarily picking winners or losers. At the same time, the recommendations supported a competitive marketplace for capable manufacturing vendors. Finally, the recommendations acknowledged and addressed the concerns of industry partners. Examining a wide variety of options to help maintain a healthy competitive DIB was in the best interests of all stakeholders. Options from research, development, and production of next generation armor plates to the maintenance of DIB through the FMS of legacy plates were considered appropriately against the options of stockpiling plates, issuance of IBMCs, and maintaining MSRs of competing companies. These types of DIB preservation decisions are linked to the combat readiness of the Armed Forces, national security risks, and the national economy.
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Appendix

Industrial Base Planning Guidance

DoD acquisition directives and regulations require DIB planning for acquisition programs of record. The documentation and results of DIB planning for programs is usually embedded within the acquisition and contracting strategies. The DoD Instruction (DoDI) 5000.02, Operation of the Adaptive Acquisition Framework, dated January 23, 2020, states, “PMs will consider acquisition strategies that leverage international acquisition and supportability planning to improve economies of scale, and strengthen the defense industrial base” (DoD, 2020a, p. 10). The accompanying DoDI 5000.02T, Operation of the Defense Acquisition System, provides more guidance under DIB analysis and considerations for PMs, stating that:

program management is responsible for incorporating industrial base analysis, to include capacity and capability considerations, into acquisition planning and execution. The industrial base considerations should be documented in the Acquisition Strategy and include identification of industrial capability problems (e.g., access to raw materials, export controls, production capabilities) that have the potential to impact the DoD near- and long-term, and identification of mitigation strategies that are within the scope of program management. (DoD, 2020c, p. 85)

Chapter 2, “The Industrial Base,” in Defense Manufacturing Management Guide for Program Managers contains comprehensive guidance for DIB planning (DoD, 2012). The PM’s DIB planning responsibilities originate from the Defense Production Act of 1950, of which two titles are still authorized and relevant:

- Title I—Priorities and Allocations (the authority to demand priority for defense-related products under contract)
- Title III—Expansion of Productive Capacity and Supply (the authority to provide incentives to develop, modernize, and expand defense productive capacity) (DoD, 2012)

The authorities of the Defense Production Act of 1950 cannot force commercial companies to enter government contracts with the DoD (DoD, 2012). These titles allow the DoD to incentivize commercial industry to enter contracts with the DoD and subsequently enable the DoD to place “ratings” on the contracts. Work on “rated”
contracts would be prioritized over “nonrated” contracts. The FY11 National Defense Authorization Act changed the DoD organization for DIB policy by establishing the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy with the following responsibilities:

- Stimulate and support vigorous competition and innovation in the DIB.
- Establish and sustain cost-effective industrial and technological capabilities that ensure military readiness and superiority (DoD, 2012).

Subsequent legislation solidified the importance of DIB planning in defense acquisition programs. 10 U.S.C. 44 § 2440 required consideration of the national technology and DIB in the development and implementation of acquisition plans for each major defense acquisition program. A PM is responsible for knowing the capabilities of their DIB and integrating those considerations in their risk assessments, acquisition planning, and program implementation. 10 U.S.C. 148 identified five specific statutory requirements with the DoD for DIB planning (DoD, 2012):

- Section 2501 sets national security objectives for the DIB.
- Section 2502 establishes the DIB council, headed by the Secretary of Defense.
- Section 2503 establishes a program for the analysis of technology and the DIB.
- Section 2504 requires an annual DIB report to be submitted to Congress.
- Section 2505 requires periodic assessments of the DIB (DoD, 2012).

DoDI 5000.60, Industrial Base Capabilities Assessments (DoD, 2022) and the accompanying DoD 5000.60-H (DoD, 2013) provide policy, identify responsibilities for assessing defense industrial capabilities, and detail the process for conducting assessments of DIB capabilities. DoDI 5000.60 mandates that government funds will not be used to preserve a DIB capability unless national security requirements are at risk and unless it is both cost-effective (benefits exceed costs) and time-effective (DoD, 2022). DoDI 5000.60 also emphasizes the PM’s responsibility to perform DIB assessments for the milestone decision authority in support of program milestones (DoD, 2022). Critical to the success of any program is the ability of the acquisition team to understand the capacity, capability, and the financial
stability of vendors to produce the items required by Warfighters. Industrial base planning may include the following industrial preparedness measures (DoD, 2022):

- Modernizing or expanding facilities.
- Developing improved production techniques.
- Awarding "pilot line" contracts.
- Establishing or maintaining standby production lines.
- Maintaining a warm production base.
- Acquiring and maintaining plant equipment packages with all the necessary special tools, dies, fixtures, and special test equipment.
- Establishing and maintaining multiple production sources.
- Conducting special studies.
- Prestocking raw materials, semifinished materials, components, and assemblies.
- Multiyear contracting.
- Establishing programs to increase the retention of personnel with key technical skills.
- Recommending design changes or waivers.
- Underwriting the establishment/maintenance of U.S. production sources for critical defense material when no current U.S. source exists (DoD, 2022).

Incorporated into DIB planning is diminishing manufacturing sources and material shortages (DMSMS) management outlined in DoDI 4245.15 (DoD, 2020). DoD DMSMS management policy throughout the life cycle of all DoD items is to:

- Establish and implement risk-based, proactive DMSMS management.
- Evaluate all DoD system designs and redesigns for potential DMSMS issues.
- Implement resolutions, if necessary, to minimize or eliminate risks and negative impacts (e.g., cost, schedule delays, readiness) resulting from DMSMS issues.
- Implement improvements to DMSMS management processes (DoD, 2020b, p. 3).
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Reexamining Investments for the Future

Norene Johnson, Emily Beliles, and Nicole Brate

DAU Press

Fort Belvoir, VA
Obsolescence is a challenge for Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) systems within the Army. These challenges include lower availability of components in the supply chain, schedule delays, and higher costs. Proactive obsolescence management in lieu of reactive obsolescence management is essential to assist with understanding and mitigating obsolescence challenges. This article presents a visualization tool for evaluating the risk of obsolescence to a system’s components. The tool was developed and deployed using the R statistical software program. The visualization tool focuses on the areas of component design life, procurement lead time, cost growth, and the number of manufacturers producing the component. These obsolescence properties are combined in the visualization tool to measure the level of obsolescence risk exposure from the supply availability of the components. The visualization tool was first demonstrated using simulations of 10 systems based on a mix of risk levels with respect to the obsolescence properties. The visualization tool allows a user to input component-level data for their system and compare it with two reference systems: the best case when all variables are low risk (i.e., proactive) and the worst case when all variables are high risk (i.e., reactive). The reference systems are included to help practitioners quickly understand their systems level of obsolescence risk from the supply availability of the components. The visualization tool was then validated with publicly available data for a drone and a user study that demonstrated improved accuracy, duration, and confidence in assessing obsolescence risk.

DOI: https://doi.org/10.22594/dau.23-914.31.01

Keywords: Data visualization, diminishing manufacturing sources and material shortages, DMSMS, R Statistical Software, risk management, obsolescence, supply chain
Many important benefits are associated with proactive obsolescence management for the Army’s Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) systems. Regarding the supply chain, a common theme among the literature is the acknowledgement that proactive obsolescence offers greater availability of system components, lower costs of components, shorter component schedules, and higher system readiness (DoD, 2022). Conversely, the opposite is true for reactive obsolescence management. The challenge of obsolete components in a system is complex and can lead to unknown, limited, and/or undesired nonavailability of a needed component(s) at one or more levels within a system’s supply chain. Moreover, the current methods of tracking the risk of components becoming obsolete rely on tables and spreadsheets, which make predicting the obsolescence risk of components and systems difficult and cognitively burdensome. The likelihood of a newly produced system shortly finding itself needing a reactive obsolescence mitigation solution is high; Sandborn (2013) estimated that over 70% of electronic components are obsolete before the system is even installed. As a result, organizations often implement a more reactive obsolescence mitigation solution. In response to these current limitations, this article presents and validates a novel visualization tool to assist with managing obsolescence risk.

The challenge of obsolete components in a system is complex and can lead to unknown, limited, and/or undesired nonavailability of a needed component(s) at one or more levels within a system’s supply chain.

The increase of obsolete components in a system is inevitable over the life cycle as a system ages (Herald et al., 2009). The changing parameters based on advancing technology impact long-lived systems in many areas, such as interfaces, weights, power needs, materials, etc. Several data points are available during system component acquisition that are indicative of obsolescence risk across a variety of parameters. However, it is difficult to efficiently identify and understand the obsolescence risk of components and integrate risk mitigation efforts at the system level, particularly as obsolescence risk scales continuously from low to high. The visualization tool developed and presented in this article alleviates the cognitive
burden of assessing and potentially misclassifying the obsolescence risk of a system, especially in the case of multiple systems.

Our motivation in developing this visualization tool was to ease the cumbersome process practitioners use to identify and assess the risk of obsolescence in their systems by assisting and strengthening the practitioner’s ability to detect and understand the level of obsolescence risk. We hypothesize that a practitioner’s ability to assess obsolescence risk could be improved by developing a visualization method to assist with assessing risk. For purposes of this article, we use risk criteria to develop and validate a visualization tool. Visualization tools have been shown to decrease cognitive load (Anderson et al., 2011; Yelizarov & Gamayunov, 2014), which can be useful in managing obsolescence risk of complex systems.

The visualization tool developed and presented in this article alleviates the cognitive burden of assessing and potentially misclassifying the obsolescence risk of a system, especially in the case of multiple systems.

There currently exists a gap in DoD’s risk management literature of a detailed methodology in an open-source environment for visualizing the obsolescence risk of systems based on supply factors of components. Zheng and Terpenny (2013) discussed the ontology of obsolescence management, where they proposed a method for integrating obsolescence information using shared vocabulary, but their method did not present a visualization component. Specific to spacecraft obsolescence and to help with prioritization of payloads, Geng et al. (2016) introduced a framework to assist with obsolescence mitigations. Meyer et al. (2004) defined obsolescence drivers and developed a simplified life-cycle cost model to aid in decision making. Dependency analysis and diagramming have also been used to identify key points of migrating software applications to prolong system life (McComb et al., 2002). Systems Modeling Language has been used to aid obsolescence mitigation with models that build on current methods to deliver risk mitigations and strategies that assist system engineers and program managers with putting into practice off-the-shelf options in military systems (Constantine & Solak, 2010). Similarly, Zolghadri et al. (2018) presented a case study using system architecture modeling to predict the impact of diminishing manufacturing sources and material shortages
(DMSMS) on a system by quantifying costs and delays. While these previous methods highlight the importance of considering obsolescence mitigation, they require the user to model system complexity in a way that this article aims to simplify.

The properties in this article's tool can be expanded to visualize data in other newly developed obsolescence predictive models in computed tomography equipment obsolescence (Reyes-Santias et al., 2023). The obsolescence risk management discussed in this article complements current research in the mapping and visualization of supply chains, as well as visualizing supply network constraints (Blackhurst et al., 2018; Nuss et al., 2016). Moreover, this obsolescence risk management research deepens the current research in supply chain feedback (Chellin & Miller, 2023b). Furthermore, policy outlined in various DoD publications on DMSMS, such as DoD (2020, 2022, 2023), are complemented based on the research presented in this article showing improvements when using obsolescence management visualizations vs. traditional methods. The goal of this article is to offer a tool to assist with achieving successful obsolescence mitigation. Successful obsolescence mitigation can be defined as “finding solutions to negate or significantly lessen the effect of C5ISR functionally outdated system components” (Chellin & Miller, 2023a).

**Problem Statement**

The benefits of proactive obsolescence management are often not realized because a team cannot see its obsolescence risk early, as well as track the changing risk levels among the components over time. The ability to view the risk level associated with obsolete components within a system is not readily available. This lack of early visibility contributes to missing an opportunity to save schedule, reduce costs, and maintain systems readiness. Additionally, it slows the tracking of
activities implemented to reduce the level of obsolescence risk within a system. The traditional tools of tables and spreadsheets are cumbersome vs. the advantages of data visualization for both scalability and automation (De Leon & Parameswaran, 2022). Also, the complexity of this problem is challenging at many levels within the supply chain. A missed assessment of one or more components anywhere in the supply chain will be realized when it is too late for proactive mitigation approaches.

“The benefits of proactive obsolescence management are often not realized because a team cannot see its obsolescence risk early.”

Research Questions

Currently, a gap exists in researching and visualizing the variables that contribute to obsolescence risk with C5ISR systems. Visualizing system obsolescence can provide further insights by informing potential risk mitigations’ paths to reduce the risk of obsolescence. The objective of this article is to provide techniques to characterize the obsolescence of a system within the parameters of proactive and reactive obsolescence, through the development and use of a visualization tool. The outcome of this research can assist acquisition practitioners and researchers by instilling a better understanding of how to interpret component-level information that contributes to both success or failure in mitigating obsolescence risk. The following research questions are addressed in this article:

1. How can a data visualization tool facilitate proactive and mitigate reactive obsolescence risk management?
2. How can data visualization be used to understand component-level obsolescence risk for a system?
3. How does visualization improve human understanding of obsolescence risk in a system?
Materials and Methods

Data simulation was used to generate various systems that ranged in values of obsolescence properties. Then, data visualization techniques were used to develop a visualization tool to provide visual comparisons and interpretation of system obsolescence risk. Lastly, the visualization tool was validated using a case study with an off-the-shelf drone and through user testing with C5ISR subject matter experts. This study has Institutional Review Board approval from Colorado State University.

"A missed assessment of one or more components anywhere in the supply chain will be realized when it is too late for proactive mitigation approaches."

Obsolescence Properties

Four system component properties were included to model a system’s obsolescence risk: design life, procurement lead time, cost growth, and number of manufacturers. These variables are based on obsolescence management research conducted by Chellin and Miller (2023b), who interviewed 20 experts on C5ISR obsolescence management and reported these four variables as critical in developing an obsolescence mitigation framework. These properties are applicable across a variety of systems; for example, design life can also be referred to as time in market or product lifetime in marketing contexts. Each of the four properties measure at the component level of a system, such that a system comprises a value for each property for every component in the system. For example, a system with 100 components would have 100 values for design life, 100 values for procurement lead time, 100 values for cost growth, and 100 values for number of manufacturers. Table 1 summarizes the risk level of obsolescence based on values for these properties described by Chellin and Miller (2023b) and shown in Table 1. In this context, we can consider the combination of the component property (i.e., consequence) and risk level (i.e., probability) to comprise the overall risk of obsolescence.
Simulated System Data

Since each of the four system component properties of obsolescence had three levels of risk, 81 possible unique permutations of a system could be classified. We used multiples of 9 to obtain 10 representative systems of the possible 81 unique permutations of obsolescence risk within a system. Hence, 10 different system

<table>
<thead>
<tr>
<th>RELATIVE RISK LEVEL</th>
<th>DESIGN LIFE (YEARS)</th>
<th>PROCUREMENT LEAD TIME (MONTHS)</th>
<th>COST GROWTH (%)</th>
<th>MANUFACTURERS (N)</th>
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</thead>
<tbody>
<tr>
<td>LOW</td>
<td>12.01 - 15</td>
<td>1 - 5.99</td>
<td>1 - 9.99</td>
<td>3 - 5</td>
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<td>6 - 12</td>
<td>10 - 25</td>
<td>2</td>
</tr>
<tr>
<td>HIGH</td>
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<td>12.01 - 18</td>
<td>25.01 - 33.25</td>
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</table>

<table>
<thead>
<tr>
<th>SYSTEM ID</th>
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<th>PROCUREMENT LEAD TIME</th>
<th>COST GROWTH (%)</th>
<th>MANUFACTURERS (N)</th>
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</thead>
<tbody>
<tr>
<td>1 (PROACTIVE)</td>
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<td>LOW</td>
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<tr>
<td>9</td>
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<td>MEDIUM</td>
<td>LOW</td>
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<td>HIGH</td>
<td>LOW</td>
</tr>
<tr>
<td>63</td>
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<td>HIGH</td>
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</tr>
<tr>
<td>72</td>
<td>MEDIUM</td>
<td>HIGH</td>
<td>HIGH</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>81 (REACTIVE)</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
</tbody>
</table>
simulations were conducted, ranging from the lowest to the highest obsolescence risk based on the criteria in Table 1. Table 2 shows the 10 systems selected and the risk allocation assigned to each system for the simulations. The system with the lowest obsolescence risk (i.e., low risk across all four properties) is the most proactive, while the simulated system with the highest obsolescence risk (i.e., high risk across all four properties) is the most reactive. The remaining systems (i.e., systems 9, 18, 27, 36, 45, 54, 63, 72) are a combination of variable parameters for low, medium, and high obsolescence risk.

Data for these systems were generated using the R statistical software program (version 4.1.0). Data were simulated at the component level for each system; for each of the 10 systems, each system was comprised of 1,000 simulated components. Hence, for each system, 1,000 observations were simulated for design life, 1,000 for procurement lead time, 1,000 for cost growth, and 1000 for number of manufacturers. A uniform distribution was used to randomly select values for each component within the possible range of values for each risk level, as defined in Table 1. For example, system ID 1 (proactive) was assigned low risk across each of the four obsolescence properties. Thus, its simulated values for design life for each component were randomly and uniformly selected from 12.01 to 15; from 1 to 5.99 for procurement lead time; from 1 to 9.99 for cost growth; and 3 to 5 for number of manufacturers.

**Physical Drone System**

In addition to the 10 simulated systems used to develop and demonstrate the visualization tool, we also evaluated the tool using an actual drone system to explore the usability and value of the visualization tool with a real, physical system. This provided a validation of the visualization tool, while also providing a concrete example to utilize it. The drone used in this study was selected specifically because all component information was publicly and commercially available. The specific drone system itself is not crucial but rather representative of an exercise in using the visualization tool.

An online tutorial website for a fully open source multicopter drone was used to get a list of drone system components (i.e., bill of materials) (Chamorro, 2017). We then searched on Amazon for these individual parts to build the drone and estimate procurement lead time, cost growth, and number of manufacturers. Procurement lead time was estimated based on Amazon delivery time for that component, which
represents a component that is already sitting on the shelf, ready to ship. The cost growth was estimated using the percentage change from the searched component compared to its recommended replacement or alternative component. The number of manufacturers was based on how many unique sellers on Amazon sold that part. (Note: We did not verify that each seller was an independent manufacturer, but as this is merely an exercise in using and validating the tool, this assumption does not undermine the exercise.) Lastly, design life was estimated at the drone level due to limitations in component-level information. This was calculated by looking at the product history timeline of drone generations for one of the top drone designers, DJI, which includes details about popular commercial drone brands (DJZ Photography, 2022).

TABLE 3. DRONE COMPONENT OBSOLESCENCE DATA

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>DESCRIPTION</th>
<th>DESIGN LIFE (YEARS)</th>
<th>PROCUREMENT LEAD TIME (MONTHS)</th>
<th>COST GROWTH (%)</th>
<th>MANUFACTURERS (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRAME</td>
<td>F450 Drone Frame Kit 4-Axis Airframe 450mm Quadcopter Frame kit with Landing Skid Gear</td>
<td>1.11</td>
<td>0.83</td>
<td>22.23</td>
<td>3</td>
</tr>
<tr>
<td>TRANSMITTER</td>
<td>Turnigy TGY-i6 AFHDS Transmitter and 6CH Receiver (Mode 2)</td>
<td>1.11</td>
<td>0.27</td>
<td>-12.22</td>
<td>1</td>
</tr>
<tr>
<td>CHARGER</td>
<td>Turnigy E3 Compact 2S/3S LiPo Charger 100–240v</td>
<td>1.11</td>
<td>0.39</td>
<td>30.45</td>
<td>4</td>
</tr>
<tr>
<td>PROPELLERS</td>
<td>9450 White Propeller</td>
<td>1.11</td>
<td>0.27</td>
<td>0.0215</td>
<td>3</td>
</tr>
<tr>
<td>FLIGHT CONTROLLER</td>
<td>AfroFlight Naze32 Rev5 Acro FunFly Controller</td>
<td>2.68</td>
<td>0.27</td>
<td>267.75</td>
<td>1</td>
</tr>
<tr>
<td>BATTERY</td>
<td>ZIPPY Flightmax 2800mAh 3S1P 30C</td>
<td>2.68</td>
<td>0.45</td>
<td>69.81</td>
<td>3</td>
</tr>
<tr>
<td>MOTORS</td>
<td>MultiStar Size 2212 With CW/CCW</td>
<td>2.68</td>
<td>0.27</td>
<td>57.66</td>
<td>3</td>
</tr>
<tr>
<td>ELECTRONIC SPEED CONTROLLER (ESC)</td>
<td>Afro ESC 30 Amp (Simonk Firmware)</td>
<td>2.68</td>
<td>0.29</td>
<td>17.74</td>
<td>3</td>
</tr>
</tbody>
</table>
We calculated the difference in time between first-generation to second-generation releases for identical drone models, for which we found information on four drones: Phantom, Ronin, Inspire 1, and Mavic Air. The mean design life for these four drones was 1.896 years (SD = 0.786). We then assigned mean + SD (i.e., 2.68) to half of the components and mean – SD (i.e., 1.11) to the other half of the components. The component-level data used in the visualization for this drone are summarized in Table 3.

**Visualization Tool**

The visualization tool was developed and deployed using RStudio (R version 4.1.0), which is available at https://www.r-project.org/. The tool is comprised of a .csv file and a .R script file. The .csv file allows the user to input their component-level data, similar to Table 3. The .R script file only requires the user to change their file path to where the .csv file is saved and the file path to where they want the visualization output [.png] file. The .R script file also allows the user to modify the ranges for the obsolescence risk levels if they desire; otherwise, the default ranges match those presented in Table 1.

**TABLE 4. COMBINATION OF SYSTEM CONDITIONS PRESENTED TO USERS**

<table>
<thead>
<tr>
<th>TOOL</th>
<th>NUMBER OF COMPONENTS</th>
<th>OBSOLESCENCE PROPERTY</th>
<th>OBSOLESCENCE LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE</td>
<td>10</td>
<td>Design Life</td>
<td>LOW RISK</td>
</tr>
<tr>
<td>VISUALIZATION</td>
<td>10</td>
<td>Cost Growth</td>
<td>HIGH RISK</td>
</tr>
<tr>
<td>TABLE</td>
<td>25</td>
<td>PLT</td>
<td>MEDIUM RISK</td>
</tr>
<tr>
<td>VISUALIZATION</td>
<td>25</td>
<td>NUMBER OF MANUFACTURERS</td>
<td>MEDIUM RISK</td>
</tr>
<tr>
<td>TABLE</td>
<td>50</td>
<td>DESIGN LIFE</td>
<td>LOW RISK</td>
</tr>
<tr>
<td>VISUALIZATION</td>
<td>50</td>
<td>PLT</td>
<td>HIGH RISK</td>
</tr>
<tr>
<td>TABLE</td>
<td>75</td>
<td>NUMBER OF MANUFACTURERS</td>
<td>LOW RISK</td>
</tr>
<tr>
<td>VISUALIZATION</td>
<td>75</td>
<td>Design Life</td>
<td>MEDIUM RISK</td>
</tr>
<tr>
<td>TABLE</td>
<td>100</td>
<td>Cost Growth</td>
<td>MEDIUM RISK</td>
</tr>
<tr>
<td>VISUALIZATION</td>
<td>100</td>
<td>PLT</td>
<td>HIGH RISK</td>
</tr>
</tbody>
</table>
User Evaluation

We conducted user testing of the visualization tool with 21 participants, all of whom had experience with mitigating the challenges of C5ISR obsolescence. The purpose of the user evaluation was to compare a user’s ability to recognize a system’s obsolescence risk modeled on conventional tables using our visualization tool.

We used the Qualtrics online survey platform to conduct the user evaluation. Each participant received a link to the Qualtrics survey. Participants were not provided with any training prior to using the visualization tool; it was their first time seeing it. Participants were asked to identify the obsolescence risk of 10 different systems based on one of the four obsolescence properties. Five of the systems required using the traditional table method to assess obsolescence risk, and five of the systems required
using the visualization tool. The number of components within the system increased from 10, to 25, to 50, to 75, to 100. Table 4 further details the combination of parameters presented to the users.

Examples are shown in Figure 1 (table tool) and Figure 2 (visualization tool) of how the tools were presented to each participant in the Qualtrics survey.

Three dependent variables were collected from each participant to assess performance for each of the 10 systems.

1. Participants were asked to identify if the system was low, medium, or high risk. Only one response was correct, thus their accuracy was scored as correct or incorrect.
FIGURE 3. ALL 9TH SYSTEMS’ OBsolescence Risk Visualization with Proactive (Low) and Reactive (High) Reference Systems

- **Design Life Years Before Obsolescence**
  - Low Risk
  - System 9
  - System 18
  - System 27
  - System 36
  - System 45
  - System 54
  - System 63
  - System 72
  - High Risk

- **Procurement Lead Time**
  - Low Risk
  - System 9
  - System 18
  - System 27
  - System 36
  - System 45
  - System 54
  - System 63
  - System 72
  - High Risk

- **Obsolescence Cost Growth %**
  - Low Risk
  - System 9
  - System 18
  - System 27
  - System 36
  - System 45
  - System 54
  - System 63
  - System 72
  - High Risk

- **Number of Manufacturers**
  - Low Risk
  - System 9
  - System 18
  - System 27
  - System 36
  - System 45
  - System 54
  - System 63
  - System 72
  - High Risk
2. Participants were not aware, but their response time for the previous question was recorded by Qualtrics. Hence, the time it took for them to review the tool and select low, medium, or high risk was evaluated.

3. Participants were also asked how confident they were in their assessment of low, medium, or high risk. Their confidence was measured on a 5-point Likert scale (extremely unconfident to extremely confident). The data were analyzed using Wilcoxon signed-rank tests with $\alpha = .05$.

## Results

### Visualization Tool Overview With Simulated Data

The output of the visualization tool yields a single figure comprising four plots, representing the risk of a system across the four obsolescence properties: design life, procurement lead time, cost growth, and number of manufacturers. Each system is plotted as one bar within each plot, where the content of the bar is generated based on the individual components in a system. In each of the four plots, the proactive (low risk) and reactive (high risk) systems are included to provide a reference to the risk level of the user’s system. Below each plot is the legend for the respective component property, where the range of possible values can be modified by the user, as needed, to match the selected component properties.

These references provide a quick and straightforward assessment of a system’s risk. The following visualization (Figure 3) demonstrates the output of the visualization tool for the simulated data, where every ninth system of the possible 81 risk permutations of low, medium, and high were simulated. Each quad displays one of the four obsolescence properties with a legend below each respective plot. This demonstrates the scenario where a user would be interested in visualizing the obsolescence risk of eight systems compared to the low and high risk reference systems. The visualization tool would generate a bar for as many systems for which the user inputs data into the .csv file.

Similarly, a user might be interested in only visualizing one system relative to the low and high risk reference systems. Figure 4 demonstrates this for a single system, where simulated system 45 was selected. For reference, system 45 was simulated such that its components were medium risk for design life, high risk for procurement lead time, medium risk for cost growth, and low risk for number of manufacturers.
FIGURE 4. VISUALIZATION TOOL OUTPUT FOR SIMULATED SYSTEM 45

FIGURE 5. USER EVALUATION STUDY FOR VISUALIZATION TOOL OUTPUT: DRONE OBSOLESCENCE RISK VISUALIZATION TOOL
Visualization Tool for Drone Case Study

Next, a validation of the tool was performed using a case study with the real drone system (Figure 5). This validates the applicability of the tool beyond simulations to engineered systems, as represented by the drone in this case study. This validation depicts how the visualization tool can be used to characterize the obsolescence risk for a system. The versatility of this tool is further demonstrated by visualizing datasets outside the parameters of the predefined reactive reference system. For example, the drone’s obsolescence cost growth well exceeds the simulated high risk parameters. In this case, the practitioner would need to decide if the reference system should be revised for these types of systems or if this is a characteristic outcome due to other factors, e.g., supply chain disruptions and/or high inflation. However, in either case, the obsolescence cost growth for this drone is fully visualized, and this ability to visualize it increases the likelihood for successfully mitigating its obsolescence risk.

Visualization Tool User Evaluation Study

We conducted the user evaluation with 21 subject matter experts on obsolescence management and C5ISR systems, where 10 were government employees and 11 were employees from industry partners. Out of these 21 participants, 14 were male and 7 were female. The participants included 10 engineers, 5 logisticians, 5 project managers, and 1 resource manager. All the participants had at least 1 year of experience in their area of expertise, for which 16 of the participants reported at least 15 years of experience. Participant accuracy was assessed based on whether they identified the correct level of risk for each system, where a 1 represented correct and 0 for incorrect. Each participant’s scores were summed for the visualization tool (our novel method) and the table tool (the traditional method). Since each participant assessed five systems using the visualization tool and five using the table tool, their accuracy scores could range from 0 (worst) to 5 (best). A Wilcoxon signed-rank test was used to compare these scores, where the paired test was used since each participant had a score for visualization and table methods. Participants’ overall accuracy scores were significantly better using the visualization tool (median = 4, SD = 0.78) compared to the table tool (median = 3, SD = 1.72), \( W = 2.5, p = .0011 \). The time it took participants to determine the obsolescence risk of each system was also evaluated. Since participants completed the task for systems with 10, 25, 50, 75, and 100 components using the visualization and table tools, their completion times were paired by visualization/table for each component number. No statistically significant
difference was noted in the time it took to determine obsolescence risk with only 10 components. However, for 25, 50, 75, and 100 components, the data visualization tool method was significantly quicker than the [traditional] table method. The results of these Wilcoxon signed-rank tests are summarized in Table 5.

Similar to completion time, participant confidence level in their assessment was also compared at each component number for visualization vs. table method, paired for each participant and synopsized in Table 6. No statistically significant difference was noted in self-reported confidence between the two methods for 10, 25, 50, and

### Table 5. Comparison of Task Completion Times (in Seconds) for Visualization and Table Tools

<table>
<thead>
<tr>
<th>Number of Components</th>
<th>Visualization Time Median (SD)</th>
<th>Table Time Median (SD)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>77.86 (79.70)</td>
<td>66.92 (149.42)</td>
<td>.7079 (ns)</td>
</tr>
<tr>
<td>25</td>
<td>21.14 (97.92)</td>
<td>41.42 (91.39)</td>
<td>.0263</td>
</tr>
<tr>
<td>50</td>
<td>18.02 (23.86)</td>
<td>38.02 (54.84)</td>
<td>.0038</td>
</tr>
<tr>
<td>75</td>
<td>18.73 (34.87)</td>
<td>47.85 (39.20)</td>
<td>.0101</td>
</tr>
<tr>
<td>100</td>
<td>11.65 (6.53)</td>
<td>37.27 (42.09)</td>
<td>.0002</td>
</tr>
</tbody>
</table>

*Note.* ns = nonsignificant

### Table 6. Comparison of Confidence (1 extremely unconfident to 5 extremely confident) in Assessment for Visualization and Table Tools

<table>
<thead>
<tr>
<th>Number of Components</th>
<th>Visualization Confidence Median (SD)</th>
<th>Table Confidence Median (SD)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>4 (0.83)</td>
<td>4 (1.06)</td>
<td>.1675 (ns)</td>
</tr>
<tr>
<td>25</td>
<td>4 (0.83)</td>
<td>4 (1.19)</td>
<td>.7609 (ns)</td>
</tr>
<tr>
<td>50</td>
<td>4 (0.91)</td>
<td>4 (1.09)</td>
<td>.1875 (ns)</td>
</tr>
<tr>
<td>75</td>
<td>4 (0.48)</td>
<td>4 (0.83)</td>
<td>.7825 (ns)</td>
</tr>
<tr>
<td>100</td>
<td>5 (0.60)</td>
<td>4 (0.65)</td>
<td>.0093</td>
</tr>
</tbody>
</table>

*Note.* ns = nonsignificant
75 components. However, participants were significantly more confident in their assessment of obsolescence risk for 100 components using the data visualization tool method. Therefore, the participants were mostly unaware of their improved performance using the data visualization tool method compared to the traditional method.

Lastly, at the end of the study, participants were asked what method they preferred. The vast majority, 71.43% of the participants, reported that they preferred the visualization tool method when analyzing the obsolescence risk of multiple systems.

**Discussion and Conclusion**

The objective of this article is to demonstrate how visualization techniques could be used to improve obsolescence risk management. Managing obsolescence risk is an area that can benefit greatly from data visualization because of the many components and variables that need to be considered when managing the obsolescence risk of a system. Multiple variables are considered to assess a system’s obsolescence risk; in some cases, a lower number is better (e.g., procurement lead time), and in other cases a higher number is better (e.g., design life). The ability to visualize these and other variables among many components within a system is a powerful risk management tool. Furthermore, the visualization tool presented in this article provides simulated reference systems visualizing the goal of proactive and the undesired state of reactive obsolescence risk management. This ability to visualize the obsolescence risk for one or more systems fills a current gap in the risk management literature and in the practice of obsolescence management. Adding visualizations for variables that indicate the risk of obsolescence for a system’s components will assist with the technical analysis and focus needed to proactively mitigate an underlying obsolescence challenge for a system’s components.

Components within a system in the long-lived systems in the Army’s C5ISR community are repeatedly challenged by obsolete components (Chellin & Miller, 2023b). This challenge requires focused effort to both identify and mitigate obsolescence challenges. Moreover, understanding the obsolescence status of a system is cognitively burdensome because the data are usually captured in a spreadsheet with many lines to consider. Therefore, intense focus is required to understand the size and multiple properties of an obsolescence challenge.

The range of these visualizations can be applied from a small team focusing on one system to large teams that focus on many systems. The visualization tool presented in
this article can enable researchers and practitioners to gain a deeper understanding of areas that shape the obsolescence risk management position of one or more systems using risk and several variables that indicate the availability of the system’s components. This research provides visualizations of systems that are proactively managed, reactively managed, and systems that exhibit the characteristics of both. The research further complements, builds upon, and can provide feedback to the ontology, mapping, and DoD policy that seeks to improve the obsolescence management of C5ISR systems. The longer the life cycle of a system, the more likely the system is to have increasing obsolescence challenges.

Moreover, this research visualizes the obsolescence of a single system, several systems, and many systems by providing a tool to assist with the visualization of obsolescence risk. The ability to model and understand several properties that contribute to obsolescence, as well as to visualize these properties as variables, provides an opportunity to understand the obsolescence status of a system and assists with the planning of mitigations to resolve or lessen the negative impacts of obsolescence. Also, the application of visualizing key aspects of obsolescence and risk provides a powerful tool that can aid stakeholders with understanding and mitigating obsolescence risk. This research demonstrates data visualization as a tool to facilitate proactive obsolescence risk management and highlights several areas on which to focus in mitigating reactive obsolescence risk management.

The software tool developed in R supports data visualization in the context of gaining a deeper understanding of the component-level obsolescence risk of a system. Also, visualizing obsolescence risk improves understanding, forecasting, and mitigating of system obsolescence by visualizing the obsolescence risk of a system’s components. For example, if the obsolescence visualization tool indicated high risk due to one supplier and long procurement lead times, a potential mitigation is an early redesign.
of the components using a common standard that multiple suppliers could produce. This mitigation strategy could facilitate quicker adjustments to future changes in technology by following the standard, which would assist with increasing the number of suppliers and shortening the procurement lead time. Similarly, suppose the same system also had medium to high risk in cost growth, this same mitigation would also assist with decreasing that risk. By increasing the number of suppliers, a competition is now ongoing to assist with decreasing the supply and demand systemic pressures that are contributing to the cost growth. This would also mitigate a capacity issue because now the orders for components can be spread among multiple suppliers, which may lead to shortening procurement lead time. As a result, multiple suppliers can produce the components in parallel. This article validated the use of the visualization tool over traditional methods of tables through subject matter experts in the area of C5ISR systems and obsolescence. The results showed that users were more accurate, quicker, and confident in their obsolescence risk assessments using the visualization tool. They also overwhelmingly preferred the visualization tool.

One limitation of this research is that the obsolescence properties and their ranges were developed with a relatively small sample size focused on the U.S. Army’s C5ISR systems (Chellin & Miller, 2023b). However, the visualization tool allows users to add or modify the existing obsolescence parameters to provide flexibility in this limitation. Another limitation is that this research focuses on visualizing a small set of variables (i.e., four obsolescence properties). Future research could be conducted with additional variables to gain deeper insights, such as inventory and risk of procuring counterfeit parts. We have made the code available for free at https://zenodo.org/records/10606851 to assist the community of acquisition practitioners and researchers (Chellin & Gallegos, 2024). Additionally, future research could be conducted with a larger sample size and in an area outside of C5ISR systems. Moreover, the presented obsolescence visualization tool could be paired with data sources internal to an organization. It could then be adjusted to include additional categories to better align with an organization’s needs and better provide defense acquisition and defense industry users with new insights on obsolescence management mental models (Chellin & Miller, 2023a). Another logical pairing is with system health performance indicators (Mohammad-Amini et al., 2021) to assist with formulating proactive obsolescence management mitigation approaches. Other research opportunities early in the system life cycle include
model-based systems engineering containers (Morgan et al., 2021) to architect the visualization of obsolescence properties and to inform future phases of the system.

"The results showed that users were more accurate, quicker, and confident in their obsolescence risk assessments using the visualization tool. They also overwhelmingly preferred the visualization tool."

In conclusion, this article provides a new method using visualizations in R to aid systems obsolescence management for practitioners and researchers. The data visualization tool allows one to see if the obsolescence risk posture of a system is reactive or proactive. This then gives the team the ability to focus on the parameters that contribute to higher obsolescence risk and to take an appropriate action to mitigate the risk. The visualizations of obsolescence risk improve the understanding of acquisition practitioners and researchers to forecast the obsolescence risk of a system and implement one or more mitigations to address both the short-term and long-term obsolescence challenges. This method allows early detection of obsolescence risks and also allows the acquisition practitioner, researcher, and management early assessment and timely implementation of actions to mitigate obsolescence risks. Lastly, this obsolescence visualization tool will deepen the knowledge and understanding of obsolescence management and support supply sustainment and availability of critical components for all stakeholders.
References


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**Featured Book**

*Becoming a Data Head: How To Think, Speak, and Understand Data Science, Statistics, and Machine Learning*

**Author:** Alex J. Gutman and Jordan Goldmeier

**Publisher:** John Wiley & Sons

**Copyright Date:** 2021

**Hard/Softcover/Digital:** Paperback, 272 pages

**ISBN-13:** 9781119741749

**Reviewed by:** Philip Broyles
Review:

In *Becoming a Data Head*, award-winning data scientists Alex Gutman and Jordan Goldmeier pull back the curtain on data science and give you the language and tools necessary to talk and think critically about it. *Becoming a Data Head* is a complete guide for data science in the workplace, covering everything from the personalities you will work with to the math behind the algorithms. The authors have spent years in data trenches and sought to create a fun, approachable, and eminently readable book. Anyone can become a Data Head—an active participant in data science, statistics, and machine learning. Whether you’re a business or acquisition professional, engineer, executive, or aspiring data scientist, this book is for you.

The authors’ purpose in this book is to bring the data mindset to any member of an organization. They argue that traditional analytics, big data, and Artificial Intelligence (AI) are not separate silos but instead are highly interrelated. The authors hypothesize that organizations produce undesirable or incorrect data science results due to three primary causes: (a) data problems are complex, (b) analysts and stakeholders stop thinking critically about data problems, and (c) a communication gap exists between data scientists and decision makers.

Content in this book is presented in four major themes: (a) thinking like a data head, (b) speaking like a data head, (c) understanding the data scientist’s toolbox, and (d) ensuring success by recognizing common errors and understanding human factors when working with big data. Vignettes are used throughout to make the material relatable.

Gutman and Goldmeier advise decision makers to first state the problem while making sure to focus on things that matter. From there, leaders should identify stakeholders, prepare the team if results are not as expected, and establish an exit strategy, such as knowing when to cut their losses or harvest wins. This encourages leaders and managers to be active participants.

The text defines data and distinguishes data from information. Further delineations of the types of data are presented, as are ways data scientists collect, structure, and think statistically about the data. The
imperative for leaders is to question data, ask where it originated, ask who collected the data, and determine how outliers and missing data were handled in the analysis. Other tips include probing for insights on sampling biases and validating that the data is representative of the specific problem under study.

Common statistical tools and error-checking methodologies are discussed in detail. Two chapters explore probabilities and statistics in depth. Those chapters set the groundwork for a discussion on linear and logistics regression. The authors then venture into more complex tools such as machine learning and AI by explaining how text can become numbers for analysis and how images can be “seen” by computers. The reading ultimately transitions to current state-of-the-art content on neural networks and deep learning while making comparisons to the functionality of the human brain.

The final section, “Ensuring Success,” addresses pitfalls, biases, and seven types of communication breakdowns that typically occur in organizations. The book concludes by describing three types of data personalities—data enthusiasts, data cynics, and data heads—and how to work with all types.

For acquisition professionals, the Under Secretary of Defense for Acquisition and Sustainment tasked the 2020 Committee on Improving Defense Acquisition Workforce Capability in Data Use to outline improvements across a broad range of acquisition functions, including cost estimating, contracting, contract management and cybersecurity, among others. The committee developed numerous recommendations that will have positive impact on acquisition activities to include greater access to data (by removing data silos) and ability to use data proactively within the DoD. This book complements DoD’s efforts in this space and has applicability for those who may practice, manage, or lead efforts involving data science.
Each issue of the *Defense Acquisition Research Journal* will bring to the attention of the defense acquisition community a topic of current research, which has been undertaken by the DAU Virtual Research Library team in collaboration with DAU’s Director of Research. Both government civilian and military Defense Acquisition Workforce readers will be able to access papers publicly and from licensed resources on the DAU Virtual Research Library Website: https://dau.libguides.com/daukr.

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*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.
**Commission on Defense Innovation Adoption: Interim Report**

*Eric Lofgren, Whitney McNamara and Peter Modigliani*

**Summary:**

The DoD needs to accelerate adoption of cutting-edge technology from the leading edge of commercial and defense sectors. To address the DoD’s innovation adoption challenge in light of the urgency of today’s geopolitical environment, this interim report advances 10 policy recommendations for Congress and the Pentagon, focusing on three key areas: (a) reforming acquisition, (b) overcoming barriers to innovation, and (c) and revising specific Planning, Programming, Budgeting, and Execution structures.

**APA Citation:**

Innovation for Digital Transformation and Policy Analytics

Dr. Hanumanthrao Kannan, Dr. William Rouse, Dr. Nirav Merchant, Dr. Alejandro Salado, Dr. Young-Jun Son, and Dr. Zoe Szajnfarber

Summary:

This report presents the initial results of an Acquisition Innovation Research Center Policy Test Laboratory (AIRC PTL) study and was performed by the research team over a period of 2 months. The goal of this project was to establish an initial reference architecture to support the development of the PTL. The government has identified several obstacles to inform effective and efficient acquisition policies. Effective modeling, simulation, and analysis of acquisition policies require a multidomain, multiscale approach. However, existing research in acquisition policy analysis has primarily remained siloed. Policy researchers lack a platform that enables sharing, reusing, or integrating the methods, models, and data developed and/or generated by different research teams in different projects. Government envisions a PTL as a potential solution to this need.

APA Citation:


Strengthening the Defense Innovation Ecosystem

Brodi Kotila, Jeffrey A. Drezner, Elizabeth M. Bartels, Devon Hill, Quentin E. Hodgson, Shreyas S. Huilgol, Shane Manuel, Michael Simpson, and Jonathan P. Wong
Summary:

DoD has created an ecosystem of defense innovation labs, hubs, and centers to help bridge the technology innovation gap between private-sector firms and the U.S. military. These various defense innovation organizations (DIOs)—the Defense Innovation Unit, the Joint Rapid Acquisition Cell, the National Security Innovation Network, the Air Force’s AFWERX, and the Army Applications Laboratory, among others—have proliferated over the past two decades and operate independently of one another to address specific but often similar needs. The authors identify and assess challenges to quickly harnessing emerging commercial technologies for military use within the existing defense innovation ecosystem, especially when much of this innovation is the product of individuals and businesses that have traditionally not worked with DoD.

APA Citation:

The Dynamics of Secrecy Management in Open Innovation: The Case of the Defense Industry

Jonathan Langlois

Summary:

To keep up with the pace of development in civilian innovation, defense firms have recently launched a series of initiatives to search and integrate external innovation into their internal development process. This progressive shift toward open innovation has triggered specific challenges for defense firms to attract, exploit, and protect innovative assets stemming from outside their traditional military milieu. From a theoretical perspective, the emergence of the open...
innovation phenomenon in such a secretive environment unlocks new possibilities to understand the rules and practices of concealment that actors deploy in this new paradigm. Thus, the author conducted a three-year qualitative study inside a large defense firm to follow this research opportunity.

**APA Citation:**


**The Nature of the Defense Innovation Problem**

*Dr. Melissa Flagg, Molly Nadolski, Jose Sanchez, Tom McDermott, and Dr. Philip S. Anton*

**Summary:**

The DoD asked that we assess its innovation problem. This effort was spurred by the department’s continued struggle to engage the innovation ecosystem effectively to support improved acquisition, capabilities, and military outcomes. The authors considered the existing approaches that are heavily focused on process solutions and the standing up of new offices. It was clear that the challenge remains. As a result, they took a step back to clearly define the problem, its causes and challenges, and potential remedies rather than risk blindly identifying and chasing rapid or simple solutions that may not resolve the fundamental issues with obtaining and fielding the right innovative defense capabilities. As such, this report is an effort to look at the challenge from first principles and truly understand the nature of the defense innovation problem.
Framework for Organizational Needs of Innovation in the Department of Defense

Jennifer M. Taylor

Summary:

The framework lays out Bureaucratic Environment Attributes and Innovation Environment Attributes that answer the central question of how to allow innovation to flourish while operating in a large-scale bureaucracy. These attributes describe the elements that need to be considered to support organizational decision making, whether in realigning the innovation ecosystem, aligning efforts, or developing new strategies. This framework can assist in indicating what pieces should be centralized to allow more freedom for innovation at the DoD—such as hiring, budgeting, acquisition management, and other activities that benefit from consistency.

APA Citation:

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.

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- 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).

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*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.

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- Situation/problem
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- 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/.

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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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9820 BELVOIR RD STE 3
FORT BELVOIR, VA 22060-5565
Statement Required by the Act of August 12, 1970
Section 3685, Title 39, U.S.C. Showing Ownership, Management, and Circulation

The Defense Acquisition Research Journal (ARJ) is published at the Defense Acquisition University (DAU), Fort Belvoir, VA. DAU publishes four issues annually. The managing editor was Olena McLaughlin, and the Assistant Editor was Christopher McGowan at the time of filing, and the publisher is the DAU Press. All are collocated at the following address:

Defense Acquisition University
ATTN DAU PRESS (DEFENSE ARJ)
9820 Belvoir Road, Suite 3
Fort Belvoir, VA 22060-5565

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