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Dynamic Consequences of Cost, Schedule, and Performance Within DoD Project Management

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Project management has been a constant challenge for the U.S. Department of Defense (DoD) acquisition community. While most DoD projects are technologically advanced, the tools and methods to manage these projects are the same as for simple, repetitive projects. The authors argue that traditional approaches fail because they only evaluate the relationships between two of the three elements of cost, schedule, and performance. Instead, they have developed a system dynamics model that allows cost, schedule, and performance to interact and influence one another. This model is complementary to other research and intended to be usable by the practicing project manager. The results from model runs will provide consequences for three potential control alternatives in DoD project management.



The search for the ideal form of DoD project management has existed since the dawn of DoD projects and is driven by a desire to reduce the DoD project failure rate. In fact, many external observers as well as quite a few DoD acquisition professionals would probably say that more DoD projects fail than succeed. Many researchers have explored the reasons for general project failure in great detail. They have developed many theories that withstand academic scrutiny, but the range of even simply understanding the nature of projects varies depending on project characteristics, the project industry, and where researchers decide to restrict their studies. Ultimately, no one solution makes DoD or any other domain of project management work. That the DoD project management industry has not had more research is somewhat surprising given the large number and size of DoD projects. However, this is a common problem in most project management domains (Love, Edwards, & Irani, 2008). Certainly, DoD could gain more appreciation and insight from an improved understanding of the way it conducts project management, which is different from other industries.

Background

5 According to the U.S. Government Accountability Office (GAO), half of the major defense acquisition programs are not meeting cost goals, and 80 percent have increasing unit costs (GAO, 2011). GAO further notes that between 2008 and 2010, the 98 major defense acquisition projects have grown in budget by 9 percent (GAO, 2011). In the Fiscal Year (FY) 2012 budget request, the U.S. Department of Defense (Comptroller) asked for \$85.3 billion of its \$553.1 billion budget, or approximately 15.4 percent for major defense acquisition projects (Comptroller, 2011).

Frequently, budget pressure, schedule pressure, or changing user demands are cited as the reasons for both commercial and DoD failures (Meier, 2010). However, these challenges have been present for as long as projects have been undertaken, and the trend within DoD is getting worse instead of better (GAO, 2011). The fact that many of these projects are developmental and have little or no basis for comparison is a fair excuse for why initial cost, schedule, and performance estimates prove to be incorrect. However, DoD project management needs to develop approaches to overcome the current trends. The first step to improvement is a solid understanding of how most DoD project management

works. The goal of the authors' research is to ultimately provide insight into the practical application of alternative decisions within DoD project management from the perspective of the government project manager.

Project management has existed since man began building things. However, many researchers define the beginnings of the formal discipline of project management with the U.S. Polaris missile development and use of critical path methods in the 1950s (Lyneis, Cooper, & Els, 2001; Pich, Loch, & De Meyer, 2002; Tishler, Dvir, Shenhar, & Lipovetsky, 1996; Williams, 2005). Therefore, a close connection exists between DoD projects and formal project management, but not all project management is the same. Tishler et al. (1996) note that defense projects are different from commercial projects due to a larger, more interdisciplinary design and higher technological risks. Despite this early bond between DoD and project management, many U.S. senior DoD leaders as well as the U.S. Congress have expressed the view that U.S. DoD project management needed improvement as early as 1970, and have since changed the acquisition policy guidance nine times (Ferrara, 1996).

Sorenson (2009) provides an in-depth overview of the history of U.S. DoD acquisition. He notes that the "current defense acquisition process is constructed on a foundation of distrust" (Sorenson, 2009). By this he means that the distribution of power as well as the extensive oversight is all in place to ensure that everyone is involved in doing the right thing, and to avoid the illegal and immoral past history of highly publicized procurement irregularities related to defense acquisition. He notes that there are variations in how projects are executed and decisions that are made on varying projects. Sorenson (2009) further comments that the Secretary of Defense has (though infrequently) terminated acquisition programs, but Congress never has. He highlights many of the problems with defense acquisition, from poor cost estimates to development delays to changing requirements to excessive oversight (Sorenson, 2009).

Other researchers have found that many DoD project managers underestimate cost and schedule due to the failure to understand complexities involved as well as seemingly futile efforts to correct an underperforming project, which often results in blaming exogenous variables as opposed to endogenous ones (Lyneis & Ford, 2007). They further add that a great deal of research exists noting general theories on the need to reduce elements of project management rework cycles, but domain-specific advice or research is limited (Lyneis & Ford, 2007).

Ford and Dillard (2009) address this deficiency using a system dynamics model of the JAVELIN missile development program that allowed them to evaluate the strengths and weaknesses of “evolutionary acquisition” by comparing two strategies for system development.

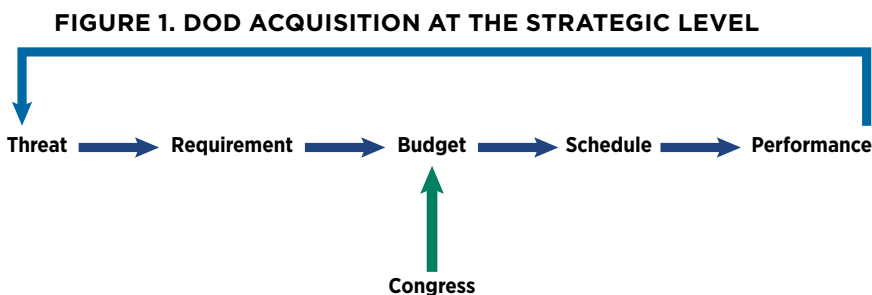
System dynamics also has a long history with DoD. One of the earliest uses of system dynamics within DoD was in the diagnosis and legal support for delay and disruption claims by Ingalls Shipbuilding against the U.S. Navy in the development of the amphibious assault ships in the 1970s (Cooper, 1980). This model was effective, but was taken from the perspective of the contractor in the 1970s. An extensive system dynamics model was used to evaluate the general field of software development (Abdel-Hamid & Madnick, 1991). Black and Repenning (2001) developed a generic system dynamics model based on a commercial manufacturing new product development to evaluate how early failure to apply appropriate resources to a project (or multiple projects) results in a “firefighting” phenomenon that results in poor project performance. Taylor and Ford (2006) further reinforce this research with the same phenomenon and additional “tipping point” analysis as applied to construction management. These research results are highly valuable, but focused on the commercial world that does differ from government project management in that government project management is more focused on managing a contractor who is doing the development. More recent uses of system dynamics models have been in the actual prosecution of combat operations in the areas of command and control, search and rescue, and irregular warfare (Coyle, Exelby, & Holt, 1999; DoD Announces, 2008). All of these models are valuable and insightful, but they do not provide practicing project managers much specific detail in ways to perform their jobs better.

In the last 3 years, Ford and Dillard’s JAVELIN system dynamics model is one of the most recent models and does provide good insight into varying acquisition approaches to a project. Both the current authors and they agree that a DoD project manager must still accomplish a single-block development even within the larger evolutionary acquisition; and attempting to document and model all external influences on DoD project management may be futile. Therefore, our approach is to develop a historically based, empirical model that produces the final cumulative cost, schedule, and performance results in a manner that allows us to evaluate the consequences of three simple control alternatives within any larger acquisition framework. Thus, our model could one day be incorporated into Ford and Dillard’s to provide additional understanding

of the dynamics of DoD project management. We believe our research will help practicing DoD project managers better understand positive and negative consequences of simple project control alternatives that they may consider.

Dynamic Hypothesis

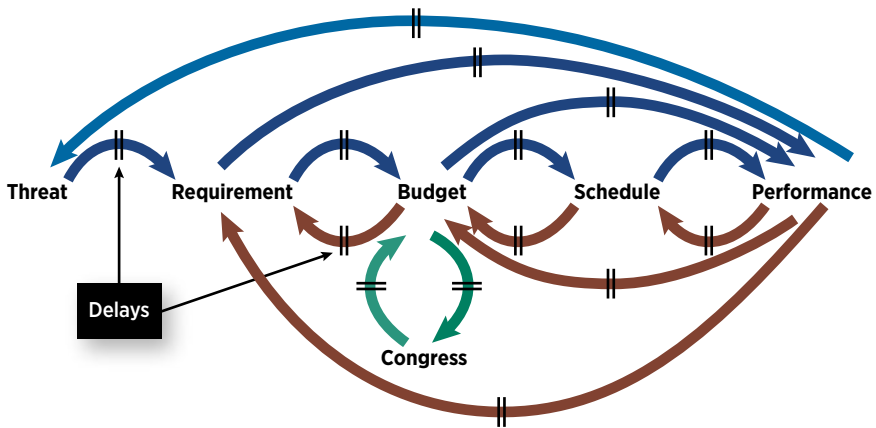
If you were to ask many DoD professionals to describe how acquisition truly works at the strategic level, they would describe a framework similar to that depicted in Figure 1. In this figure, one strategic activity is all or the vast majority of what influences the next downstream strategic activity. Therefore, a given threat (or change in threat) causes a new delivered requirement that changes a budget estimate, which causes the schedule estimate, and the end result is a performance expectation. At the budget event, Congress may intervene and adjust up or down the budget, which impacts the downstream activities. Eventually, the expected performance will have an impact on the threat. While this figure is relatively simple to understand, the problem is that it ignores the speed of change in many of these subactivities (i.e., budget development every 2 years while the requirements may change every year or less) and ignores other impacts of the subactivity interaction. It further assumes that a single change can be controlled or managed with “simple processes” such as through the monitoring of a work breakdown structure or earned value management. Previous research has shown these techniques may be effective if there are relatively few or no unknowns, but they prove inadequate when there are many unknowns or the true state of the variable may not be known for some time (Dvir & Lechler, 2004; Thomas & Mengel, 2008).



As an alternative, the authors suggest that DoD professionals adopt a mental framework like that shown in Figure 2. In this figure, all of the same activities as Figure 1 are present. However, Figure 2 illustrates

that delays are present and every activity impacts every other activity. This means that an adjustment to the budget will impact schedule and performance over time. That this is a more accurate depiction of the real world is usually not in question, but the major issue is how we deal with this. The authors believe that a system dynamics model will serve as an effective tool to better understand what is going on and to propose an alternative for improved system response. In other words, we hope to find a better way to perform DoD project management for the practicing project manager.

FIGURE 2. MENTAL FRAMEWORK



Model Methodology

It is important to first note that the authors subscribe to the belief that DoD project management as a system is poorly understood. Therefore, our objective is to better understand the system and its responses through the use of an empirical model. Because of this objective, our model is relatively simple and strives to show several aspects of the system and its dynamic behavior over time that may help improve the overall results. The model is shown in Figure 3.

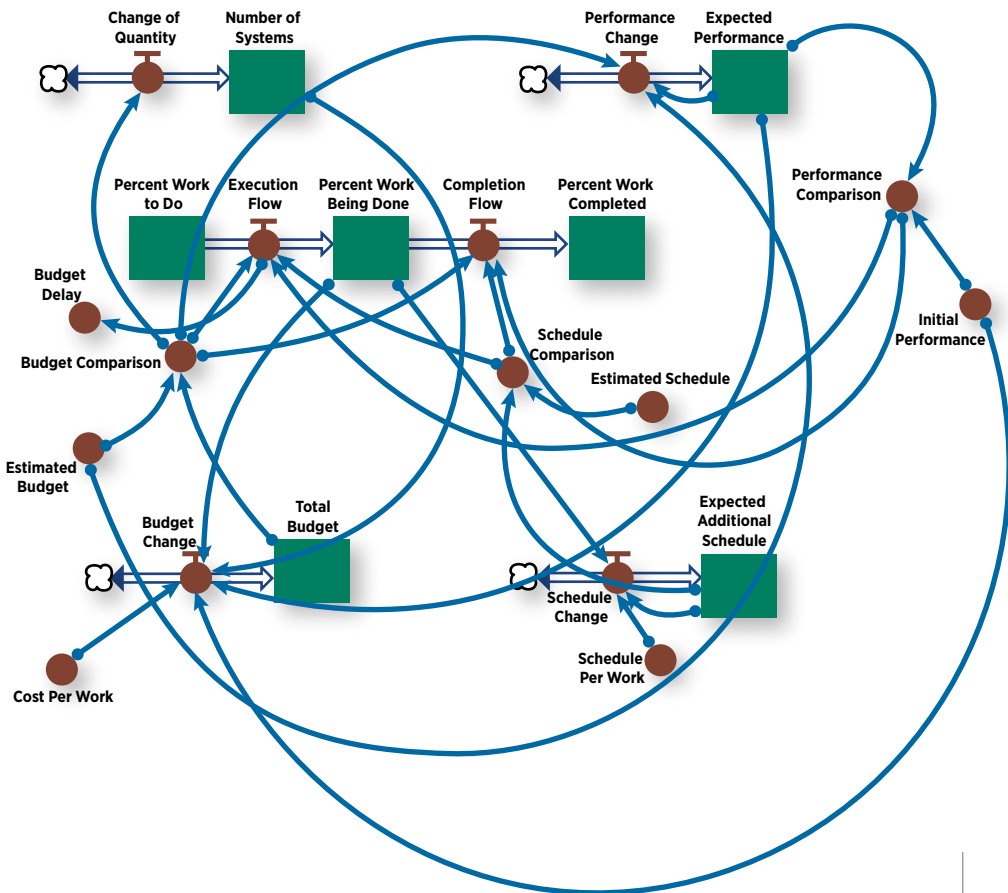
The foundation of our model is a work flow process surrounding system design/understanding. Our work flow process is very simple and defines system design/understanding project work of any kind as a percentage in one of three states: work to be done, work in progress, and work completed. The completion of all work would equate to a perfect understanding of the system being acquired, which should be the goal



of all projects. While we make a simplifying assumption that all work is equal in priority and execution, we believe that over the entire project life cycle, this is the ideal case and appropriate for our objective. With all other influences being removed, our work flow will complete all activities within 15 years, which is appropriate for most DoD projects. In our baseline model, no unknown work or rework is included. While this is certainly not accurate nor representative of the real world, our goal is to best understand the ideal case before moving to more intricate situations.

To allow for dynamic consequences, control of starting and completing work is done through a comparison of the projected or estimated budget, schedule, or performance to the actual budget, schedule, or performance. In the case of the budget comparison, we have incorporated a 2-year delay due to the DoD Planning, Programming, Budgeting

FIGURE 3. WORK FLOW PROCESS SURROUNDING SYSTEM DESIGN/UNDERSTANDING



and Execution process where a project budget is submitted, and about 2 years later the actual approved budget is delivered. (We use the terms “budget” and “cost” interchangeably in this model for simplicity, and are only focused on total system design and production costs, not the actual total life-cycle costs that include sustainment and disposal.) When the difference between the estimated budget, schedule, or performance and the actual budget, schedule, or performance is positive (i.e., the project is under cost and/or ahead of schedule and/or less capable than initially desired), then work is allowed to start and be completed at an accelerated rate corresponding to an increase in work execution. However, when the difference in the estimated budget, schedule, or performance and the actual budget, schedule, or performance is negative (i.e., the project is over cost and/or behind schedule and/or more capable than initially desired), then the work is slowed to a decelerated rate corresponding to a slowing of work execution or delaying of work. As an example, if the actual budget is 25 percent over the estimated budget, then the work initiation and completion rates are slowed by 12.5 percent due to the 2-year delay. In this model, budget and schedule are equally important and contribute the same to the work rates. Therefore, a situation with a 25 percent over budget and a 25 percent over schedule would result in a corresponding 37.5 percent reduction to the work rates.

Budget and schedule flows are based on the work in progress. The budget flow is the product of work in progress multiplied by a cost per work constant that is multiplied by the ratio of the number of systems to desired number of systems and the ratio of current performance to the desired performance. This assumes a cost reduction is associated with fewer quantities of systems and less system performance. The schedule flow is the product of the work in progress multiplied by a schedule per work constant. Either the budget or schedule flow can move in a positive or negative direction allowing for budget or schedule reductions, but it is important to note that because some amount of work is in progress at any given time, these flows will never be negative. It is also important to note that budget and schedule do not directly influence each other in this model. This is due to observations that a budget increase does not guarantee a reduction in schedule nor does a schedule increase guarantee a budget reduction (assuming all other factors are the same).

Previous project management research has addressed the interactions of cost, schedule, and work. Many earned value management and earned value schedule studies have evaluated cost, schedule, and work.

However, little to no previous research has enabled the interaction of cost, schedule, and work levels in addition to performance levels over time. Our research provides some insight into this interaction. We have incorporated performance in our model by evaluating it in two ways. First, the number of systems is another flow that impacts the total budget. As long as the project is under budget, then the number of systems will remain the same. Once the project goes above cost, then the number of systems will be reduced in an effort to reduce cost growth. This is a common behavior observed in DoD projects.

Second, performance is evaluated through a percentage of the initial desired performance. The desired performance begins at 100 percent and, like system quantity, as long as the project is under budget, will remain at its current level. Also like system quantity, once a project is over budget, the performance level will be reduced by a percentage in an effort to reduce the budget and schedule of the system development. Additionally, the amount of performance degradation could also be thought of as a quantifiable estimate of program risk, which may not be a problem or be tolerable to the project stakeholders. Both of these performance measures can be generically applied and are helpful in our gaining a basic understanding of how this model operates. While both of these performance measures impact the budget flow, only the performance level compared to the desired performance level impacts the work flow. This is due to the assumption that complete system understanding can be gained through one system and no further insight is gained from additional system production.

More detailed aspects such as rebaselining or evaluating which performance elements are reduced have been excluded so that the essential model behavior can be observed. Verification and validation of this model was done through two means. First, common system dynamics practices as referenced in Barlas (1996) were successfully conducted. Second, the authors have used a case study to validate the results of the model with actual system performance. The authors have chosen the U.S. Army's Future Combat System as the case study.

Case Study—The Army's Future Combat System

In 1999, the U.S. Army began designing the Future Combat System (FCS) as a means of preparing itself for what it expected to be the future of warfare. The Army expected to have the first unit equipped in 2011 and

the entire Army equipped by 2032. FCS involved multiple air and ground systems that were networked and interoperable. One key tenet of the FCS effort was that information could replace mass, and a second tenet was that FCS components could be deployed rapidly. The ultimate combination was a highly technical and revolutionary system-of-systems that sought to push technology and balance many competing priorities (GAO, 2008). FCS was officially terminated as a program in the summer of 2009.

While many unique and interesting dynamics surround this program, it is used as a means of verifying and validating our model. In our model, the key FCS inputs were the project cost and schedule estimates. These inputs were taken from the U.S. Congressional Budget Office (CBO, 2006) report on FCS. The model set 2005 as the base year, which was based on availability of fiscal information, and extends until 2025. Our model results of a total system cost in 2025 of \$161 billion are consistent with the Congressional Budget Service (CBS) estimates of \$160.6 billion. While the CBS may have been in error in its assessment, the fact that our model achieves similar results instills confidence in our approach. Additionally, our model estimates that when the project was killed in 2009, the number



of systems would be reduced to 14, with an estimated project completion date of 2021. These results are consistent with actual results of that time and provide the final validation of our model for general understanding.

Results

Using this model, we now turn to evaluating how varying responses impact the results. We have focused on project manager responses, and these results should hold true as long as DoD projects are evaluated against their initial (or current) estimates. The potential strategies evaluated are to Remove Controls, Ignore Schedule, Ignore Budget, and Improve Estimate. The reduction in total systems remains the same for all strategies so further discussion of it is excluded.

Remove Controls

One potential strategy to improve project success is to remove all project controls. While this model does not account for some of the uncertainties and unknowns that occur within the life of the project, it does help us evaluate a perfect-world scenario. In this perfect world with no reduction in work flow, the project completes all work by 2025, but only attains 67 percent of the desired capability. The total budget is \$147 billion, which is a 9 percent cost reduction of the baseline.

Ignore Schedule

Another potential strategy to improve project success is to ignore the schedule comparison. This alternative operates on the principle that “if you need it bad enough, you will do anything to get it.” Upon first look, this alternative achieves the lowest total cost at \$141 billion (a 13 percent reduction of the baseline) with all work completed by 2014 and a performance drop of 21 percent of the initial desired capability.

Ignore Budget

Positive results were achieved by ignoring schedule comparison so the authors were interested in what would happen if the budget comparison is ignored. In this case, the total cost was \$133 billion, which is an 18 percent reduction in baseline and looks very attractive. However, only 67 percent of the initial desired performance is achieved on system completion, which does not occur until 2032. While this strategy results in the best cost reduction, the performance and timeline are sacrificed.

Improve Estimate

Another seemingly simple strategy is to focus all efforts on knowing the true cost and schedule up front. This technique is in consonance with most systems engineering literature and does make sense with what every senior DoD acquisition leader advises. While not the focus of this research, it is another challenge entirely to determine how to accomplish this. However, this approach results in a total budget of \$210 billion or 130 percent of the baseline, with 86 percent of the desired performance delivered.

| | Total Cost | Performance Delivered | Work Completed by 2025 | Work Completed by |
|------------------|-------------------|------------------------------|-------------------------------|--------------------------|
| Baseline | \$161B | 69 percent | 100 percent | 2021 |
| Remove Controls | \$147B | 67 percent | 100 percent | 2025 |
| Ignore Schedule | \$141B | 79 percent | 100 percent | 2014 |
| Ignore Budget | \$133B | 67 percent | 77 percent | 2032 |
| Improve Estimate | \$210B | 86 percent | 100 percent | 2022 |

Looking at this data reveals two general observations. First, in a perfect world potential opportunities for cost reductions abound, but, second, they come at the expense of performance level. The largest variation in strategies regarding cost is 30 percent, which could trigger a Nunn-McCurdy breach and require congressional reporting. However, the trade-off is clearly associated with the amount of performance delivered, which at most varies by 19 percent, and when that performance is delivered, which varies at most by over 18 years. Additional statistical analysis shows that no two factors are highly correlated, but that the most likely relationship is between total cost and performance delivered.

What these results mean to a DoD project manager is that no single strategy is likely to achieve cost, schedule, and performance optimization. Project managers need to evaluate the prioritized objectives of that project's stakeholders and develop their strategies to meet those priorities. For instance, if a project is needed quickly, then ignoring how the project is comparing to the initial schedule may be the best solution. If a project needs high performance, most likely a good strategy for the project manager is to ensure the systems engineering and analysis is performed early so that the best cost and schedule estimates can be made.

Future Research and Conclusions

While these results are interesting, they are certainly not to be considered rigid rules of DoD project management. In fact, many elements and influences have been excluded in this model in an effort to gain an initial understanding of the total system behavior. The dynamics of how DoD project work is prioritized and executed, the dynamics of varying design and evaluation methods, and the dynamics and value of the three-milestone DoD acquisition gate process are all work-related influences that should be further studied. Another potential future area of study is the combination of this model into Ford and Dillard's evolutionary acquisition comparison to see if even simple control alternatives affect the results of the research. The dynamics of varying budget delays as well as the impact of congressional budget action should also be further studied. Finally, the dynamics of system quantity changes to the actual system cost is an area that can also be expanded to provide better fidelity in this model.

All of these future areas of study require significant investigation and study, and likely vary from project to project. This further supports the authors' theory that DoD project management is a highly contextual process that requires dynamic understanding of influences that sometimes do not make themselves known for some time. A system dynamics model such as the one discussed in this article could be used to best identify and predict total project behavior so that varying strategies could be evaluated for the best one in a given situation. The model could certainly be expanded and complemented, and the DoD would do well to invest more resources in exploring why projects fail (or succeed), documenting the circumstances and influences, and distributing them for widespread use in the project management arena. However, a single or even several causal factors should be avoided to explain all projects as every project is unique and must be evaluated in its unique context.

Author Biographies



Mr. Patrick R. Cantwell works as a system engineer with SURVICE Engineering Company. He is currently a PhD candidate in systems engineering at The George Washington University with research focusing on complex systems and system dynamics. Mr. Cantwell holds a BS in Naval Architecture from the U.S. Naval Academy and an MS in Engineering Management from The George Washington University.

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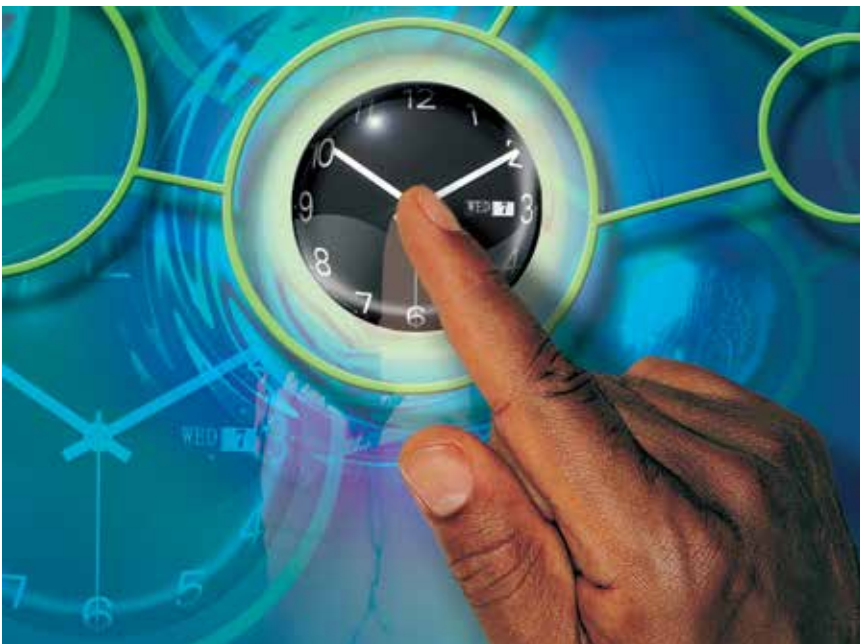
Dr. Shahram Sarkani, P.E., is professor of Engineering Management and Systems Engineering (EMSE), and director of EMSE Off-Campus Programs at The George Washington University. He designs and administers graduate programs that enroll over 1,000 students across the United States and abroad. In over 150 technical publications and in sponsored research with the National Aeronautics and Space Administration, National Institute of Standards and Technology, National Science Foundation, Agency for International Development, and Departments of Interior, Navy, and Transportation, his research has application to risk analysis, system safety, and reliability. Dr. Sarkani holds a BS and MS in Civil Engineering from Louisiana State University and a PhD in Civil Engineering from Rice University.

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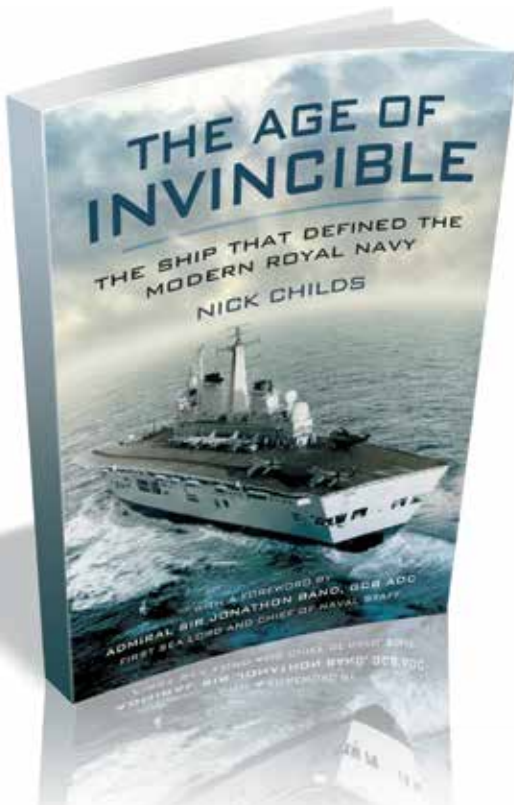
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PROFESSIONAL READING LIST

The Defense Acquisition Professional Reading List is intended to enrich the knowledge and understanding of the civilian, military, contractor, and industrial workforce who participate in the entire defense acquisition enterprise. These book reviews/recommendations are designed to complement the education and training that are vital to developing the essential competencies and skills required of the Defense Acquisition Workforce. Each issue of the *Defense Acquisition Research Journal (ARJ)* will contain one or more reviews of suggested books, with more available on the *ARJ* Web site.

We encourage *ARJ* readers to submit reviews of books they believe should be required reading for the defense acquisition professional. The reviews should be 400 words or fewer, describe the book and its major ideas, and explain its relevance to defense acquisition. Please send your reviews to the Managing Editor, *Defense Acquisition Research Journal*:
Norene.Fagan-Blanch@dau.mil.



Featured Book

The Age of Invincible: The Ship That Defined the Modern Royal Navy

Author(s):

Nick Childs

Publisher:

Pen & Sword Maritime

Copyright Date:

2009

ISBN:

978-1844158577

Hard/Softcover:

Hardcover, 208 pages

Reviewed by:

Professor David Andrews, FREng, RCNC, Professor of Engineering Design, Department of Mechanical Engineering, University College London, and former Project Director, Defence Procurement Agency, United Kingdom, Ministry of Defence

Review:

This book has a foreword by then First Sea Lord Admiral Jonathan Band, which nicely summarizes it: “this excellent and very readable account of the life [of the ship]... and the worlds from which it sprang and into which she emerged.” The book also describes the politics that led to the current build program of much larger Carrier Vessel Future (CVF) vessels. Initially, the sorry story is told of the cancellation of the CVA-01, lead ship of the first post-war carrier class. Louis Rydill, as the design manager, is quoted as feeling he was on the rack trying to achieve the capability of a Forrestal design within a displacement of 53,000 tons and a necessary, but daunting level of innovation. Meanwhile, there was ineptitude by the Royal Navy’s hierarchy in the corridors of power (contrasted later with the “A Team” 16 years on, which won the Falklands Campaign). Following the demise of British naval aviation, there was the subsequent slow and painful climb back to a fleet led by three “Through-Deck Cruisers”—only “carriers” in a limited sense once the short take off and vertical landing (STOVL) provision was incorporated.

Next, *Invincible* and her design intent is described (familiar to those involved, including this reviewer, who contributed to Nick Childs’ research, as well as coauthored the definitive technical paper in 1980 on the design—more appropriate for those who would like something technically detailed rather than this essentially strategic and personalities-focused history). Childs has caught the essentially innovative nature of this quite new concept—based on Rydill’s early helicopter cruiser studies and then Tony Austin’s coherent through-deck and all gas turbine propelled design, developed without any previous ship on which to base it (Honor & Andrews, 1982). The book then covers the Harrier ramp story well, if un-technically—there was a lot more to it than being “just welded on to the forward end of the runway.”

The nadir was reached with the early Thatcher government’s defense cutting regime with a chapter entitled “For Sale,” yet followed—mercifully, for the Navy—with the Falklands redemption of maritime capability and a chapter on “*Invincible* at War.” This should be the key chapter of the book, but is a mere 10 pages covering the immediate perspective of the Commanding Officer (then) Captain Jeremy Black, and little on how well the ship and its embarked aircraft performed. The subsequent chapter “What Lessons” focuses on the strategic rather than the tactical- or design-related lessons.

The last part of the book addresses post-Cold War peacekeeping, where the ability of carriers to project power ashore was shown to be limited with the *Invincibles* and thus made the case for the two big (65,000-ton)

carriers. On the vexing question of naval ship costs, despite the fact that it dominates the whole fleet acquisition process, Childs does not ask why the Queen Elizabeth Class (QEC) carriers, which are large but slow and minimally armed, have been subject to ever rising costs. Clearly, each major program has been, successively, the only significant United Kingdom shipbuilding program, and therefore had to shoulder the added burden of sustaining that national capability. However, this writer believes the cost escalation is also due to the persistent but false belief by politicians and wider government (including the naval hierarchy) that “value-for-money” could be delivered by giving industry the responsibility for designing and project managing naval shipbuilding, instead of leaving both in-house.

However, none of the above is addressed in Childs’ book, which largely focuses on the contributions of a succession of senior naval officers. It is a fascinating, if dispiriting, story of sacrificing the size of the rest of the fleet to keep carrier aviation alive. The uphill nature of this struggle seems consistent with the sense of a nation that has collectively lost sight of its maritime *raison d’être*. However, this is only part of the story that Childs could have addressed, as his story has a worrying lack of engagement with the underpinning engineering narrative. Could that be coincidental?

Reference

- Honor, A. F., & Andrews, D. J. (1982). HMS Invincible: The first of a new genus of aircraft carrying ships. *Trans. RINA*, 124,5.