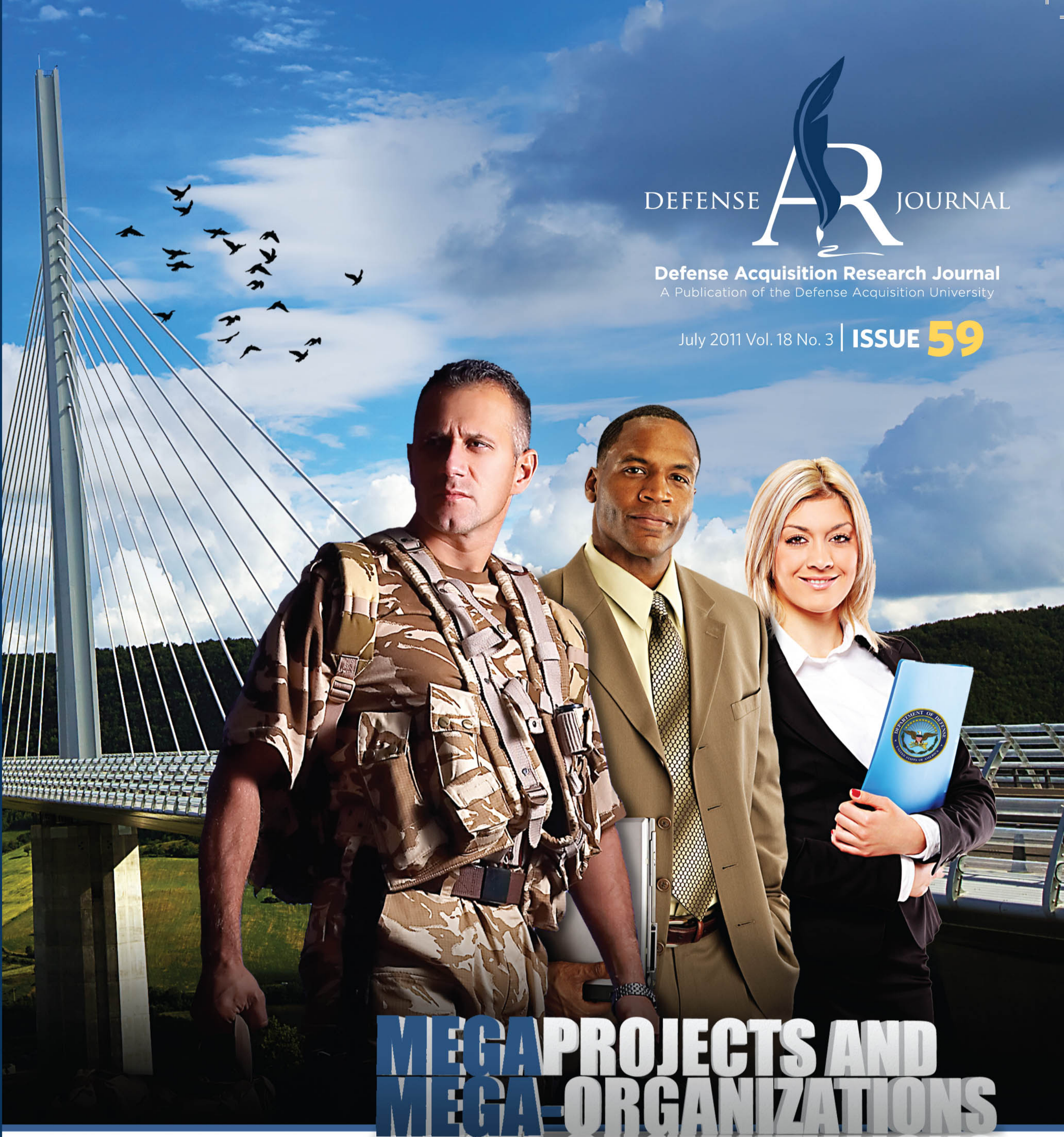

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MEGAPROJECTS AND MEGA-ORGANIZATIONS

Defense Acquisition University

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Megaprojects and Mega-organizations

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DEFENSE ACQUISITION RESEARCH JOURNAL

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The Defense Acquisition Workforce is getting younger, and its educational expectations include using advanced and innovative learning technologies. The Defense Acquisition University (DAU) has fully embraced this generational trend and has partnered with several institutions to conduct research on Advanced Learning Technologies, or ALT. One such partnership is with George Mason University's Instructional Technology Immersion Program. The partnership's goal was to examine DAU's current learning assets and identify processes and methods for utilizing innovative learning technology designs. This article summarizes this effort and describes the resulting online performance support tool called LATIST (Learning Asset Technology Integration Support Tool) developed to facilitate the understanding, selection, and integration of ALT by DAU faculty and staff.

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FROM THE CHAIRMAN AND EXECUTIVE EDITOR

The theme of this issue of the *Defense Acquisition Research Journal* is derived from the excellent review by Eunice Maytorena of *Megaprojects and Risk: An Anatomy of Ambition* (Flyvbjerg, Bruzelius, & Rothengatter) for the Defense Acquisition Professional Reading List. The book examines very large projects (characterized by major expense, complexity, innovation, and impact) and why they so often run over budget and schedule. Although the authors look at civilian projects, their findings on the role of risk and stakeholder accountability in decision making are directly applicable to major defense acquisition programs.

Leading this issue, Donald Birchler and his coauthors look at one of the elements of cost risk in defense megaprojects—the role of concurrency in the processes of development and procurement. Zoe Szajnfarber and her coauthors examine these two processes, with specific reference to the space sector, through the lens of innovation, identifying shortfalls in the current approaches, and suggesting ways to improve them. William O'Neil explores the use of "reference class forecasting," a statistical methodology pioneered by Bent Flyvbjerg (one of the *Megaprojects* authors) to attack the root cause of cost growth.

Steve Mills and his coauthors analyze the partnerships between two mega-organizations: the U.S. Department of Defense and the defense industry. Finally, Nada Dabbagh and her team show how innovative learning technologies can improve the training of the Defense Acquisition Workforce, which is the most critical element of any megaproject or mega-organization.

Dr. Larrie D. Ferreiro
Executive Editor
Defense ARJ

REFERENCE

Flyvbjerg, B., Bruzelius, N., & Rothengatter, W. (2003). *Megaprojects and risk: An anatomy of ambition.* Cambridge, UK: Cambridge University Press.

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DEFENSE ***ACQUISITION RESEARCH*** JOURNAL

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COST IMPLICATIONS OF DESIGN/BUILD CONCURRENCY

Donald Birchler, Gary Christle, and Eric Groo

Developing a weapon while in production does increase program risk and is sometimes cited as a reason for cost growth. This article explores the relationship between concurrency and cost growth in large weapon programs. The authors defined concurrency as the proportion of research, development, and test and evaluation appropriations authorized during the same years in which procurement appropriations are authorized. Their results strongly indicate that concurrency does not necessarily predict cost growth. Using classical regression techniques, the authors found no evidence supporting this relationship. To investigate other relationships between cost growth and concurrency, they also used a smooth curving technique. These experiments showed that, although the relationship is not strong, low levels of concurrency are more problematic than higher levels.

Keywords: *Weapon System; Cost Growth; Concurrency; Ordinary Least Squares (OLS) Regression; Research, Development, Test and Evaluation (RDT&E)*

image designed by Elizabeth Bailey »


CONCURRENCY
AIM-120 AMRAAM
Avionics

Typically, defense programs experience some level of concurrency; that is, production of the weapon system happens while some portions of the design are still being completed. Many people within the defense acquisition community argue that high levels of design/build concurrency ultimately lead to cost growth, as it implicitly creates a greater level of risk. For example, a memorandum from the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN-RDA) identified the high degree of concurrency in the Littoral Combat Ship as being a large contributor to the program's overall cost growth (DoD, 2006).

In a zero-risk world, the requirements, concept of operations, and substantial prior development would be completed before the release of the Request for Proposal (RFP) for the design phase. In addition, 100 percent of the design would be complete before the release of the production RFP; and all the initial material/components would always be procured and available before production started. Moreover, requirements would not change once design started, design would not change once production started, and production would flow smoothly without delays caused by late software or hardware. Thus, in a zero-risk world we would say programs have zero overlap, or concurrency, and virtually no production risk.

Unfortunately, this zero-risk approach to production planning is impossible to achieve, and even if it were, many would argue that it is not desirable. The Japanese, for example, pioneered the "just-in-time" inventory strategy, where materials essential for production are not only unavailable before production start, they are deliberately fabricated and delivered at the last possible moment to reduce in-process inventory, thus reducing storage and finance costs associated with inventory beyond what is immediately needed. No financial or technical reasons preclude production in one portion of the program while a design is completed on an unrelated portion.

Other reasons to inject plans with some design/build concurrency, despite potential increases in risk of cost growth, include (a) urgent need for the product, (b) maintaining the industrial base, (c) avoiding obsolescence, and (d) reducing exposure to requirements changes.

Consequently, major programs always retain some level of concurrency, much of which is actually an integral part of the plan (see [a] through [c], previous paragraph).

In sum, there seems to be a good case to be made that concurrency is actually desirable and possibly reduces cost, and another equally good case that it adds risk, which ultimately leads to cost growth. Unfortunately, despite decades of interest in concurrency within the acquisition community, the literature on concurrency is surprisingly thin. We found only one study conducted by the

Congressional Budget Office (1988) that specifically looked at the correlation between concurrency and cost growth. Another more recent study by RAND touched on concurrency, but was primarily about other factors that lead to cost growth (Arena, Leonard, Murray, & Younossi, 2006). However, in both cases, the studies found only a very weak correlation between concurrency (defined as the overlap between operational test and evaluation and production) and cost growth. Our study, done on behalf of the ASN-RDA, examines this relationship in more detail using a slightly different definition of concurrency and a larger data set.

Definitions

In general, a lack of consensus prevails regarding the meaning of concurrency in acquisition programs. We chose a definition that reflects the most general use of concurrency and was tractable for analysis given the data available for large acquisition programs. Other definitions for concurrency exist and likely have different implications in those contexts. Our definitions for concurrency and cost growth follow:

- *Concurrency* is the proportion of research, development, test and evaluation (RDT&E) appropriations that are authorized during the same years that procurement appropriations are authorized. This proportion is further restricted to the first 95 percent of total RDT&E spending.
- *Cost growth* is, after adjusting for quantity changes and inflation, the proportional increase of the final cost to the initial cost estimate.

We chose 95 percent of the total RDT&E appropriation because RDT&E monies continue throughout the life of the program, albeit at a much reduced rate toward the design-complete/testing-complete phase of the program. This is usually due to the ongoing need for updates and modifications, but has little bearing on concurrency issues. We were satisfied, after a little experimentation, that the 95 percent cutoff addressed this for most programs.

This measure is not a perfect proxy for concurrency. If anything, the 95 percent cutoff likely overstates concurrency. Moreover, it also misses concurrency in related programs that can have a significant effect on cost and schedule of an item such as concurrency of weapon production with development of items designated for the weapon, but being developed under other programs (such as radar, sonar, etc., which are being developed for more than one platform).

The definition for cost growth may initially appear to be overly broad, allowing for the inclusion of costs that are completely unrelated to concurrency. However, adjustments for these costs would have been much more complex, requiring systemic changes in both the initial estimates and final profiles tailored to each program. Out of concern that this process would become ad hoc, we left the definition broadly defined with adjustments made for quantity and inflation only.

Data

For measures of cost growth and concurrency, we gathered data from Selected Acquisition Reports (SARs) on the procurement and RDT&E profiles. The SARs are available in the Defense Acquisition Management Information Retrieval System (DAMIR). We reviewed this list and selected programs based on their maturity and availability of data.

On some occasions, we needed to drop new lines of production from final SARs that were absent from the first SAR. This was necessary to make apples-to-apples comparisons, particularly when controlling for quantity changes, due to the tendency of some programs to add on additional lines of production to existing procurement programs.

An illustrative case is the V-22. The initial estimate for the program was essentially for a single airframe for use by the Marines. During the course of the program, the Air Force Special Forces ordered a modified version of the airframe. This new line of production, however, cost dramatically more than the Marine version, presumably because of modifications and enhancements necessitated by the requirements for Special Forces operations. This growth in unit costs was obviously due to scope changes and not incidental to changes in program quantity or concurrency—our primary controls in this study. Fortunately, the additional RDT&E and procurement costs associated with these units were entirely funded out of Air Force appropriations, making it relatively easy to exclude these costs from the cost growth and concurrency calculations. For other programs with similar issues, where the distinction was less apparent, we reviewed budget exhibits and other publicly available budget justification materials for information to tease new subprograms away from historical program plans. This was not always possible, leading us to drop several programs from the analysis.

Method

Our approach was driven by two primary questions:

- Relative to cost growth, is there an ideal amount of concurrency that should be programmed for large acquisitions?
- If there is no "ideal," what is the relationship, if any, between cost growth and concurrency?

These questions suggested a hybrid approach, employing traditional statistics and hypothesis testing methods as well as more modern methods of data exploration. First, using Ordinary Least Squares (OLS) regression, we fit a global quadratic function to the data. The quadratic model did not fit the data well, which led us to consider a second approach—locally weighted scatterplot smoothing (LOESS). LOESS is a nonparametric regression method, which allows the data to express and inform without restricting the data to fit some function. We assessed the results of this second approach with a bootstrapping technique (Efron & Tibshirani, 1998).

To ensure that we were using completed cost growth profiles, we sampled from mature programs, defined as programs that had begun Initial Operating Capability, contained in DAMIR. Of these, after discarding programs for which we were unable to locate initial baseline cost estimates, we were left with an initial set of 43 programs. For these complete programs, we used the procurement and RDT&E acquisition profiles to calculate cost growth and concurrency.

To facilitate making statistical inferences about concurrency, we first needed to directly control a few known, significant influences. First, to control changes in base years dollars between SARs, we rebaselined all the reported costs in constant 2009 dollars using the appropriate inflation indices in the National Defense Budget Estimates, commonly referred to as the "Green Book."[1] The Green Book published indices only out to 2014, so to adjust programs that were funded past this year, we extended the indices at a fixed rate of 2 percent per year.

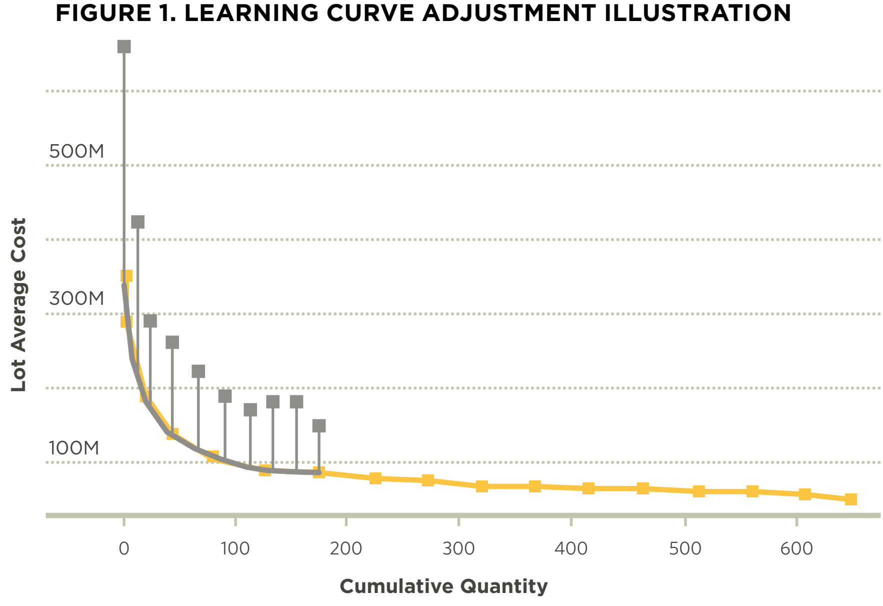
Second, we needed to adjust procurement cost growth to reflect changes in quantity. When the first SAR is published, a procurement profile shows how many units will be purchased and in what years they will be purchased. The amount of units purchased affects the procurement cost estimates via the learning curve effect. That is, the marginal costs of production drop with quantity as, with each additional unit, workers become more efficient, manufacturing processes are refined, and quality control improves. This process is incorporated into every baseline cost estimate.

Thus, it is important to adjust the original cost estimates reflected in the first SAR to account for the changes in the quantity procured. For example, a program that was originally going to purchase 100 units at a total procurement cost of $1,000 faces a budget cut by Congress leading to only 50 units being bought. A new baseline estimate could be calculated by simply taking the average cost per unit (i.e., $10) and subtracting these 50 units out of the procurement funds. Using that method, we would simply multiply 50 units by $10 to get an adjusted original cost baseline of just $500.

But that is not satisfactory. In fact, by not buying the other 50 units, the program does not experience the same level of learning, and the average cost per unit actually rises as a result. In our example cited previously, the average cost per unit would rise to something over $10, and the procurement savings would be less than $500. Using a technique pioneered by Goldberg and Touw (2003), we were able to estimate the learning curve effects for the programs in our data set and adjust the original cost baseline up or down, depending on whether fewer or more units were procured.

Figure 1 illustrates the learning curve adjustment for the F-22 program. The gray squares correspond to the quantities and costs reported in the first SAR. Notice that the gold squares curve sharply downward, but then flatten out as the total quantity increases. This pattern corresponds to an anticipated initial period of intensive

FIGURE 1. LEARNING CURVE ADJUSTMENT ILLUSTRATION



learning, which progressively tapers as the gains from learning disappear. The gold line is the estimated learning curve. What is most striking about the line is how closely it appears to fit the data, without any additional modification.

Reducing the procurement quantities increases the average costs of the units purchased, as the lower cost units at the end of the production run are not added into the total production run. Thus, if the program had followed the initial learning curve, then the lot average cost would have fallen along the upper portion of the initial estimate. These adjusted lot average costs, indicated by the gray line, form the new baseline for measuring cost growth. The gray squares correspond to the actual quantities and costs reported in the final SAR profile for the F-22 program. Despite higher than expected total costs, the average unit costs decline at a rate reflective of the original estimate. Comparing the gray squares to the gray line, we can measure cost growth as the difference between the adjusted initial estimate and the final reported cost profile for a program. This is literally the area demarcated by the horizontal dotted lines.

Most of the programs that we examined experienced some change to the procurement quantities. This adjustment required stable associations between procurement costs and units for programs between the first and final cost profiles. Unfortunately, this requirement reduced the data set to only 28 programs suitable for analysis (Table 1).

Results

For procurement cost growth, we wanted to see if there was any correlation to concurrency, as measured by the percent of RDT&E spending that occurs when procurement spending is happening at the same time. As mentioned in the method section of this article, we calculated concurrency in two ways. First, we used the first published SAR to determine planned concurrency. We then used the last SAR to calculate actual concurrency. Thus, for each element of cost growth, we looked for correlations with two different measures of concurrency.

Based upon the feedback that we received from various Navy and DoD acquisition officials, we decided that a good starting hypothesis was that concurrency follows a Goldilocks rule (not too much, not too little, but somewhere in the middle being optimal). Too little concurrency is bad for a program as serial design and production yields a longer duration (and thus more cost) before fielding of the weapon. Too much concurrency is also bad as it accepts too

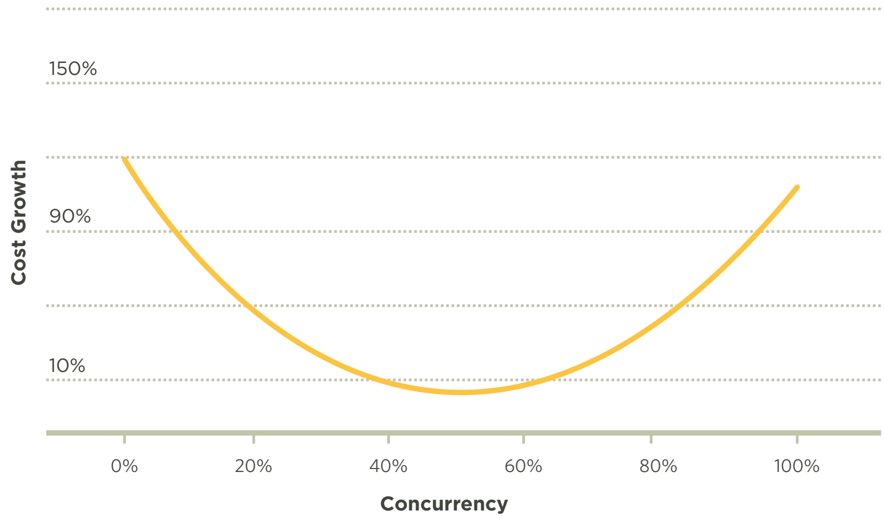
TABLE 1. LIST OF WEAPON SYSTEMS

Program	PNO
AIM 9X Sidewinder Missile	581
Air Warning and Control System Radar System Improvement Program (AWACS RSIP)	524
Bradley Upgrade	601
C-17A Globemaster III	200
CH-47F Improved Cargo Helicopter	278
EA-18G Growler	378
F-22 Raptor	265
F/A-18 E/F Super Hornet	549
Family of Medium Tactical Vehicles (FMTV)	746
High Mobility Artillery Rocket System (HIMARS)	367
Joint Air-to-Surface Standoff Missile (JASSM)	555
Joint Direct Attack Munition (JDAM)	503
Joint Primary Aircraft Training System (JPATS)	560
Longbow Apache Helicopter	831
Longbow Hellfire Missile	541
MH-60R Seahawk® Helicopter	191
MH-60S Seahawk® Helicopter	282
MHC 51 Osprey Minehunter	772
Minuteman III Guidance Replacement Program (MM III GRP)	302
Sense and Destroy Armor (SADARM)	735
Small Diameter Bomb (SDB)	354
SFW	275
SSN-21 Seawolf-class Attack Submarine	258
SSN-774 Virginia-class Attack Submarine	516
Stryker Light Armored Vehicle	299
T-45S	240
Tactical Tomahawk Missile	289
V-22 Osprey Tiltrotor Aircraft	212

much technical risk. Thus, some moderate level of concurrency would be the optimal in the sense that it minimizes cost growth. This would yield a curve similar to that shown in Figure 2.

The logic behind this approach for planned concurrency is relatively simple. Program managers plan for a certain level of funding concurrency. If they plan for too much, they may accept too much risk that could yield cost growth. On the other hand, too

FIGURE 2. HYPOTHETICAL QUADRATIC RELATION BETWEEN COST GROWTH AND CONCURRENCY



little funding concurrency forces them to create completely serial development/design and production processes that prolong program duration and also create cost growth. In sum, the planned level of concurrency forces managers to make decisions that ultimately lead to cost growth if either too much or too little concurrency is accepted.

The logic for the actual concurrency follows along similar lines. Program managers may or may not have planned for concurrency, but events led to the situation where some level of concurrency occurred, which, if too high or too low, led to excessive cost growth. Again, the assumption is that some intermediate level of actual concurrency would be the optimum.

In all cases, this simple rule can be specified with the following function, which was estimated using OLS:

$$CostGrowth = b_0 + b_1 Concurrency + b_2 Concurrency^2 + e \qquad (1)$$

Planned Concurrency

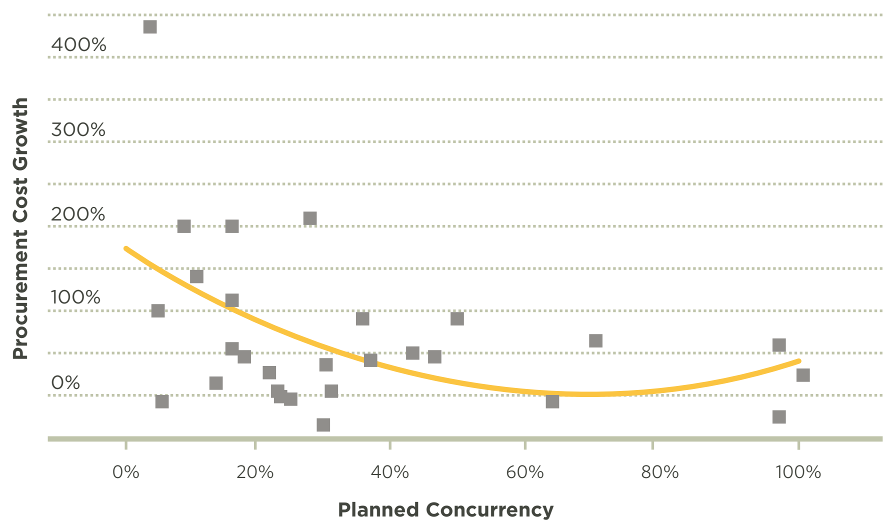
Our first model explored the relation between planned concurrency and procurement cost growth. The results are reported in Table 2.

Observe that two of the parameters are statistically significant at the .10 level (i.e., the probability that the parameters are less than 10 percent is zero), and the fitted line does give us a U-shaped curve (Figure 3). However, the adjusted R-squared is very low, which

TABLE 2. OLS RESULTS: PROCUREMENT COST GROWTH VS. PLANNED CONCURRENCY

	Estimate	Std Error	P-Value
Intercept	1.825	0.484	0.001
Concurrency	-5.014	0.465	0.052
Concurrency^2	3.667	2.273	0.119
Adjusted R^2	0.137		

FIGURE 3. FITTED CURVE: PROCUREMENT COST GROWTH VS. PLANNED CONCURRENCY



forces us to conclude that the quadratic model has little predictive power of procurement cost growth.

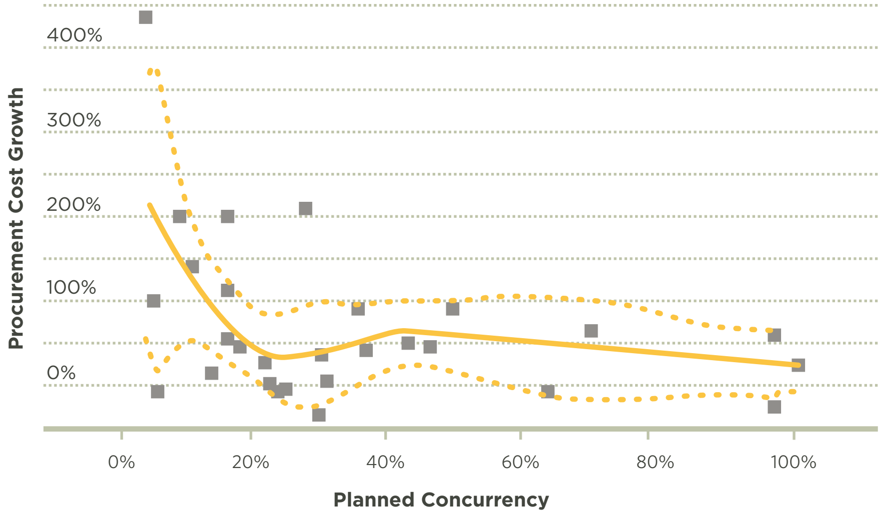
Note that much of the curvature in the model comes from one outlier. To see how well the model improves without this data-point, we ran the same model excluding the outlier (Table 3). This resulted in no improvement to the model at all and slightly less curvature.

Finally, to see if some other possible relation was evident, we ran the LOESS smooth curving routine on all of the data including the outlier. We then bootstrapped the 90 percent interquartile range to see how well conditioned the data are to the original curve. If the data are from a common model, the smoothed curves generated by the repeated sampling should be similar to the original, and the confidence intervals defined should be fairly tight around the original curve.[2] The results of these exercises using the outlier data-point discussed previously and excluding this data-point can be seen in the figures that follow.

TABLE 3. OLS RESULTS: PROCUREMENT COST GROWTH VS. PLANNED CONCURRENCY (OUTLIER EXCLUDED)

	Estimate	Std Error	P-Value
Intercept	1.097	0.390	0.010
Concurrency	-1.907	1.934	0.334
Concurrency^2	1.157	1.764	0.518
Adjusted R^2	0.021		

FIGURE 4. PROCUREMENT COST GROWTH VS. PLANNED CONCURRENCY

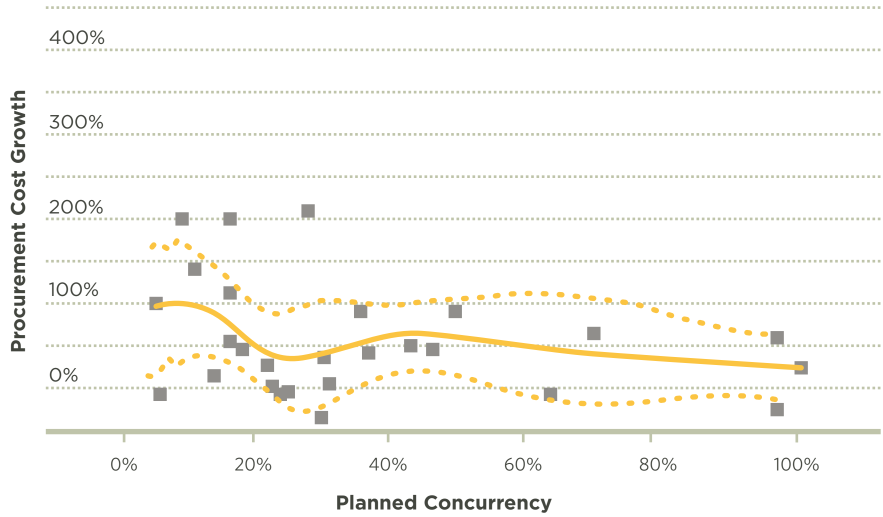


As we can see from Figure 4, the interval using the outlier data-point is extremely wide. For example, if a program had planned concurrency of .2, then, within the 90 percent interquantile range, the procurement cost growth for that program could easily range from 50 percent to over 100 percent.

To ensure that the outlier was not a significant factor in these results, we ran the same experiment excluding this data-point. This did not improve the results in any discernible way (Figure 5).

In spite of the fact that the confidence intervals around the original LOESS curves are wide, we do see a pattern in the data that suggests that low levels of planned concurrency are more problematic than higher levels of concurrency. Again, turning to the data without the outlier, we calculated the mean cost growth in procurement for those programs with planned concurrency levels under 30 percent and compared it to the means for those programs with planned concurrency over 30 percent. Those under 30 percent experienced, on average, approximately 110 percent cost growth

FIGURE 5. PROCUREMENT COST GROWTH VS. PLANNED CONCURRENCY (OUTLIER EXCLUDED)



while those over 30 percent experienced an average cost growth of approximately 50 percent. This difference was statistically different at the 95 percent confidence level.

Actual Concurrency

We next turn our attention to procurement growth as a function of actual concurrency. Table 4 shows the results of estimating the quadratic model using OLS. As in the case with planned concurrency, only the intercept parameter β_0 is significant at the .01 level. The model as a whole has an adjusted R-squared of -0.01889 indicating that the model has little explanatory power. Note also that the fitted line in Figure 6 is concave, which is the exact opposite of what our hypothesis was (i.e., a U-shaped curve).

TABLE 4. OLS RESULTS: PROCUREMENT COST GROWTH VS. ACTUAL CONCURRENCY

	Estimate	Std Error	P-Value
Intercept	1.037	0.530	0.062
Concurrency	-0.453	2.399	0.852
Concurrency^2	-0.275	2.168	0.900
Adjusted R^2	-0.019		

We also note the existence of an outlier that could exhibit a fairly large effect on the model (Figure 6). To account for this possibility,

FIGURE 6. FITTED CURVE: PROCUREMENT COST GROWTH VS. ACTUAL CONCURRENCY

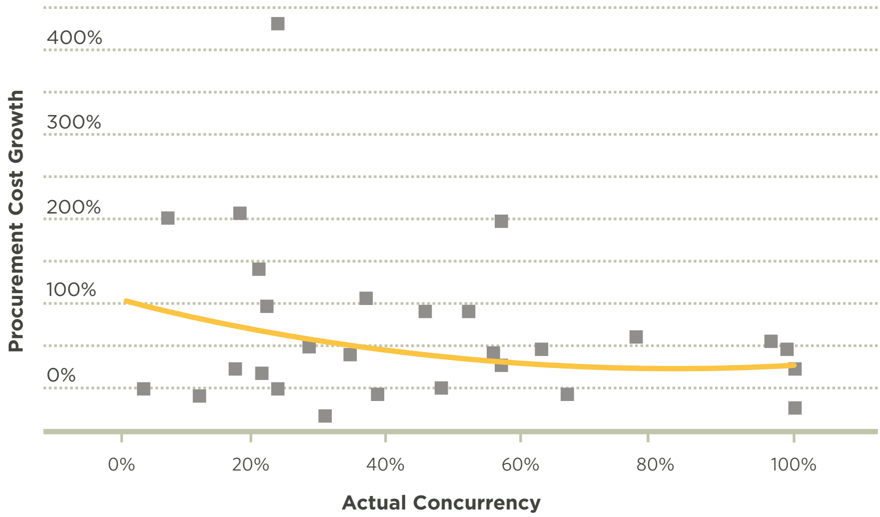


TABLE 5. OLS RESULTS: PROCUREMENT COST GROWTH VS. ACTUAL CONCURRENCY (OUTLIER EXCLUDED)

	Estimate	Std Error	P-Value
Intercept	0.762	0.376	0.054
Concurrency	-0.086	1.684	0.960
Concurrency²	-0.319	1.521	0.836
Adjusted R^2	-0.040		

we ran the same OLS model again without this outlier. The results follow (Table 5).

Using these data, the model still performed poorly with only the intercept being significant at the .10 level (Figure 7). Further, the fitted line was still concave.

Using the LOESS smooth curving method, we examined the data to see if other relationships could possibly explain the data better than a simple quadratic function. As in the case for planned concurrency, the confidence interval is very wide, indicating that actual concurrency is also a poor predictor of procurement cost growth.

To ensure that the outlier was not a significant factor in these results, we ran the same experiment excluding this data-point. This did not improve the results in any discernible way (Figures 8 and 9).

Again, we used several statistical methods to discover any relation between actual concurrency and procurement cost growth. We specifically reject the notion that actual concurrency has a

FIGURE 7. FITTED CURVE: PROCUREMENT COST GROWTH VS. ACTUAL CONCURRENCY (OUTLIER EXCLUDED)

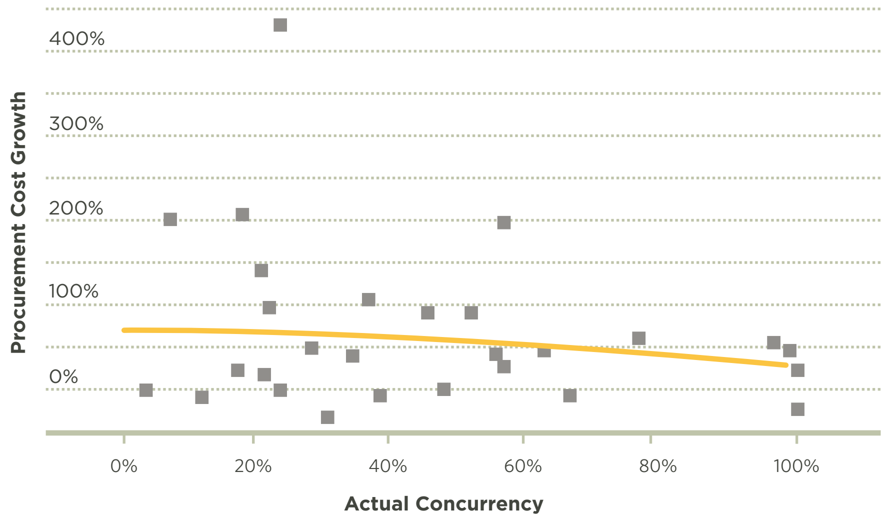
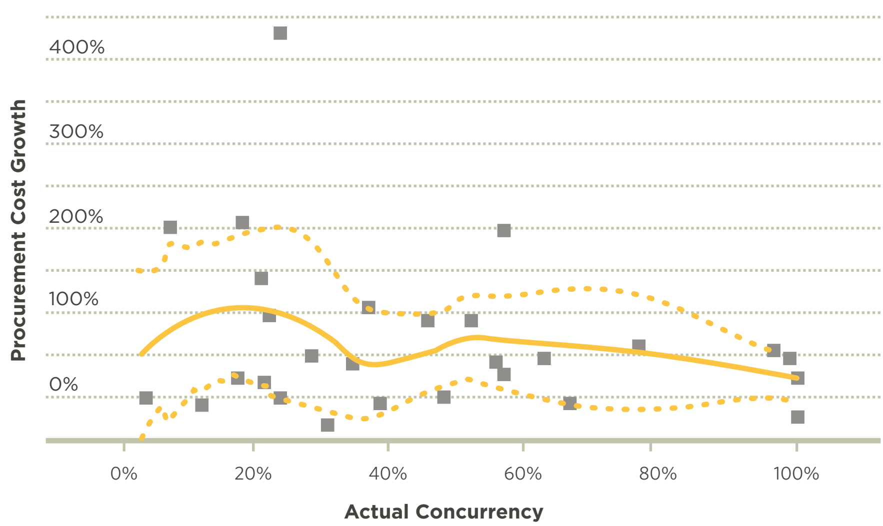
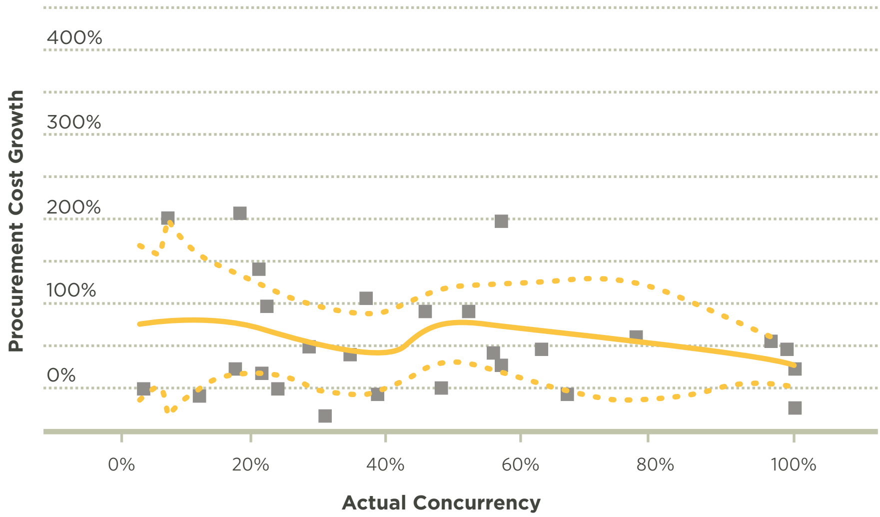


FIGURE 8. CONFIDENCE INTERVAL: PROCUREMENT COST GROWTH VS. ACTUAL CONCURRENCY



quadratic relation to procurement cost growth and find no other polynomial relationship that was consistent with the data. As is the case of planned concurrency, we do see a slight dip in cost growth for those programs with actual concurrency of approximately 30 percent although this is not as pronounced. Thus, our conclusion is that actual concurrency of RDT&E and production funding is not a strong predictor of procurement cost growth either.

FIGURE 9. CONFIDENCE INTERVAL: PROCUREMENT COST GROWTH VS. ACTUAL CONCURRENCY (OUTLIER EXCLUDED)



Conclusions for Procurement Cost Growth

In all cases, we reject the hypothesis that procurement cost growth is related to any measure of concurrency in a way described by a quadratic function. We also found no other polynomial relation that strongly supports the data. While using the LOESS curve smoothing routine on all forms of concurrency did suggest some other possible relation, bootstrapped confidence intervals indicate that any relation between the two is very weak. Thus, even if we accepted the implied curvature, the predictive power of the model for any of the concurrency measures was extremely low. In sum, we found that little if any explanatory power of concurrency by itself affects procurement cost growth. The one result that did stand out was that in the case of both planned and actual concurrency, too little concurrency was actually more problematic than too much concurrency; that is, concurrency levels under approximately 30 percent were associated with higher average levels of cost growth and higher variance as well.

Notably, our results do not indicate that concurrency is never a problem for programs and never leads to cost growth. Rather, it shows that concurrency by itself is insufficient to predict cost growth. Most likely, concurrency leads to cost growth under particular circumstances or in the presence of other factors. What these circumstances or factors are is not clear and should be examined in further research.

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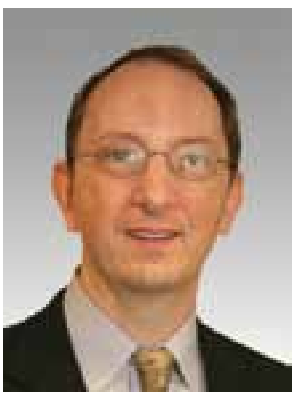
Author Biographies



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ENDNOTES

1. Quoting from the 2009 “Greenbook”:

> DoD arrives at the figures in this book using inflation rates published by the Office of Management and Budget (OMB) as a baseline. OMB typically bases their rates on Gross Domestic Product (GDP) composite rates, accounting for non-pay factors only. DoD, however, includes pay, fuel, and medical accrual factors in its composite rates. In addition, outlay rates are factored into the final DoD inflation rates. (DoD, 2009)

2. The LOESS bootstrap method is nonparametric, implying that we make no assumptions about the structure of the error term. However, we measure tightness by creating an interval around the original curve that includes 90 percent of the bootstrapped curves. These curves approximate the 5th and 95th percentiles of the true underlying distribution.

CHALLENGES TO INNOVATION IN THE GOVERNMENT SPACE SECTOR

Zoe Szajnfarber, Matthew G. Richards, and Annalisa L. Weigel

This article uses innovation theory to identify five core challenges of generating national security space innovation: (a) generating bottom-up push in a top-down environment; (b) integrating fragmented buy-side knowledge; (c) integrating fragmented sell-side knowledge; (d) matching the innovation environment to the development stage; and (e) balancing risk aversion with the need for experimentation. An analysis of how the current two-tiered process, which separates technology development from project-based acquisition, addresses these challenges, reveals that this method of separation is not a complete solution because it: (a) fails to value architectural innovation; (b) creates a disaggregated knowledge base, which exacerbates the difficulty of top-down specification and bottom-up integration; and (c) fails to generate an entrepreneurial supply-side spirit. Recommendations for improvement are provided.

Keywords: *Innovation Theory, Monopsony-oligopoly Market, Space Acquisition, Spacecraft Development, Acquisition Process, Risk Aversion*

image designed by Miracle Riese »

Characteristics of the government space market, with its monopsony-oligopoly structure and complex robust products, make encouraging innovation challenging. The Department of Defense (DoD) acquisition structure represents one example of how these challenges are addressed in an institutional setting. However, a recent string of failures has brought into question the efficacy of the system. Multiple blue ribbon panels have been convened leading to recommendations about how the current system can be improved; however, these recommendations take certain implicit assumptions of the system as a given. If a major reform is to be achieved, these fundamental assumptions must be reviewed. This article takes a step back from the acquisition process, using innovation theory to assess the intrinsic challenges of encouraging complex product innovation in a government monopsony-oligopoly. In particular, it seeks to answer the following questions: (a) What are the implications of the space sector characteristics on innovation? (b) How (or to what extent) does the acquisition system address these implications? and (c) How can these insights be used to improve acquisition in the space sector?

Implications of Space Sector Characteristics for Innovation

Despite a rich legacy of delivering impressive technology, defense acquisitions are increasingly characterized by schedule slips and cost overruns. With long development times and high complexity, national security space systems (e.g., Advanced Extremely High Frequency [AEHF], National Polar-orbiting Operational Environmental Satellite System [NPOESS], Space-Based Infrared System–High [SBIRS–High], Global Positioning System [GPS] II) have become particularly illustrative of the challenges confronting defense acquisitions (Government Accountability Office [GAO], 2007). In recent years, in an effort to address these problems, multiple blue ribbon panels have been convened. Figure 1 enumerates the recommendations of six recent reports along technical, management, and policy dimensions.

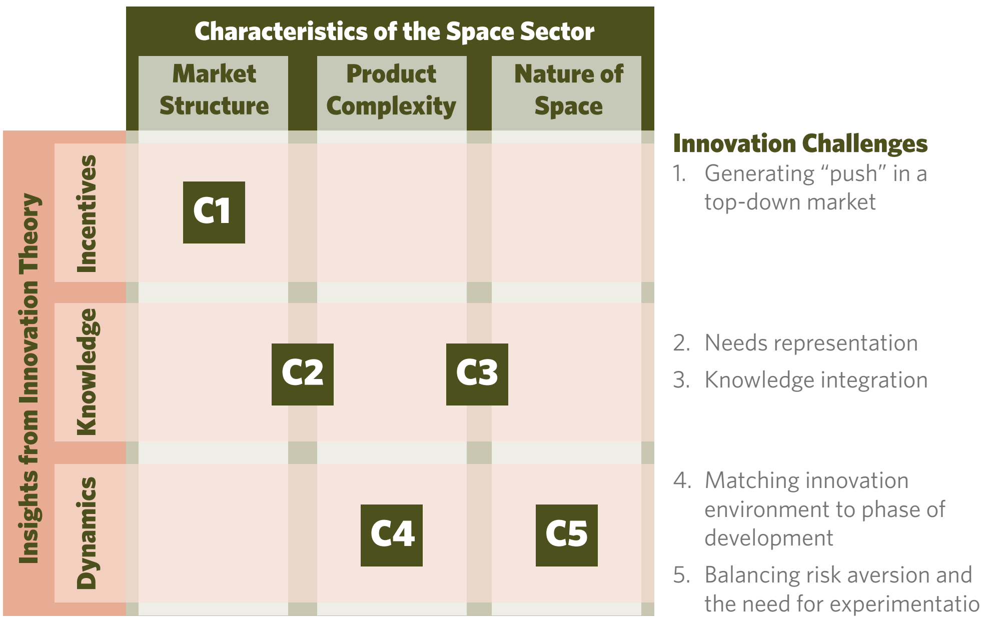
Bringing to bear the members' vast experience working in the current acquisition paradigm of large monolithic spacecraft, their recommendations emphasize a back-to-basics philosophy (i.e., maturing payload technologies outside of acquisition programs). However, with the rapidly changing requirements that characterize the needs of today's warfighter, it may be the acquisition paradigm itself that needs fixing.

FIGURE 1. KEY FINDINGS FROM RECENT STUDIES

		Rumsfeld (2001)	NDIA (2003)	Young (2003)	GAO (2006)	DoD (2006)	NRC (2008)
technology	Restore funding for testing space technologies	X			X		
	Maintain U.S. technological lead in space	X					
	Keep R&D separate from systems acquisition				X		X
	Identify technology for rapid exploitation and control						
management	Establish Presidential and NSC space advisory groups	X					
	Integrate defense and intelligence space activities	X					
	Improve front-end systems engineering (req's=resources)		X	X	X	X	X
	Improve collaboration on requirements		X		X	X	X
	Budget space programs to most probable (80/20) cost			X			
	Evaluate contractor cost credibility in source selections			X			
	Conduct independent program assessments at MDA's			X			
	Do not allow requirements creep			X	X	X	X
	Match PM tenure with delivery of a product			X	X	X	X
	Pursue incremental increases in capability				X		
	Withhold contractor award fees when goal is not met				X		
	Establish a stable program funding account					X	
	Structure development to achieve IOC within 3–7 years						X
policy	Recognize space as top national security priority	X					
	Deter and defend against hostile acts in space	X					
	End practice of appointing only flight-rated CINCSPACE	X					
	Incentivize government career paths in acquisitions	X	X	X		X	X
	Improve workforce technical competence	X		X	X	X	X
	Research systems architecting design tools		X				
	Establish mission success as guiding principle			X			
	Compete acquisitions only when in best interest of gov't			X			
	Develop integrated strategy for R&D and acquisitions				X		X
	Encourage LSI to compete major subsystems					X	
	Evaluate gov't internal training programs for acquisition						X

Note. CINCSPACE = Commander in Chief, Space Command; gov't = government; IOC = Initial Operating Capability; LSI = Lead Systems Integrator ; MDA = Milestone Decision Authority; NDIA = National Defense Industrial Association; NRC = National Research Council; NSC = National Security Council; PM = Program Manager; R&D = Research and Development; req's = requirements. Adapted from DoD, 2006; GAO, 2006; GAO, 2007; NDIA, 2003; NRC, 2008; Rumsfeld et al., 2001; Young, Hastings, & Schneider, 2003.

FIGURE 2. OVERVIEW OF INNOVATION CHALLENGES FOR DEFENSE ACQUISITIONS

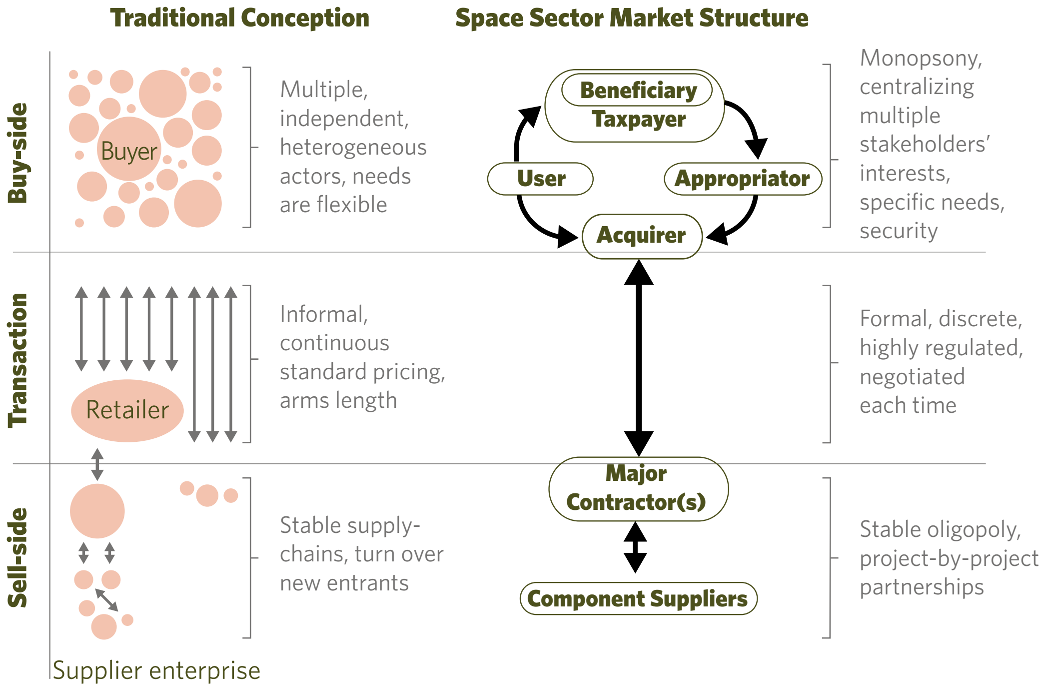


By applying strategic prescriptions on how innovation should be encouraged (as abstracted from the management and innovation literatures) to intrinsic characteristics of the space sector, five fundamental challenges to innovating in the space sector were identified: (a) generating bottom-up push in a predominantly top-down acquisition process; (b) representing the needs of a disaggregated buyer; (c) integrating fragmented sell-side knowledge from the top-down; (d) matching the innovation environment to the stage of development; and (e) balancing risk aversion and the need for experimentation. Figure 2 provides an overview of these five challenges. The following sections explain the nature of each challenge.

Challenge 1: Generating Bottom-Up Push in a Predominantly Top-Down Acquisition Process

Taking a classical economic view of innovation, market transactions are thought to be the fundamental driver of innovation. Innovation[1] occurs over time through the interaction of user needs (market pull) and seller capabilities (product push) (Rothwell & Zegveld, 1994). In a competitive market, this process happens naturally. Both the consumer's willingness to pay and the supplier's ability to deliver are revealed continuously through the mechanism

FIGURE 3. COMPARISON OF SPACE AND TRADITIONAL MARKET STRUCTURES



of price (Adams & Adams, 1972). However, in the space market, which consists of only one buyer and few sellers, the interaction only occurs when the monopsony buyer expresses a need. As a result, the transaction is less effective as a mechanism for revealing preference-capability information.

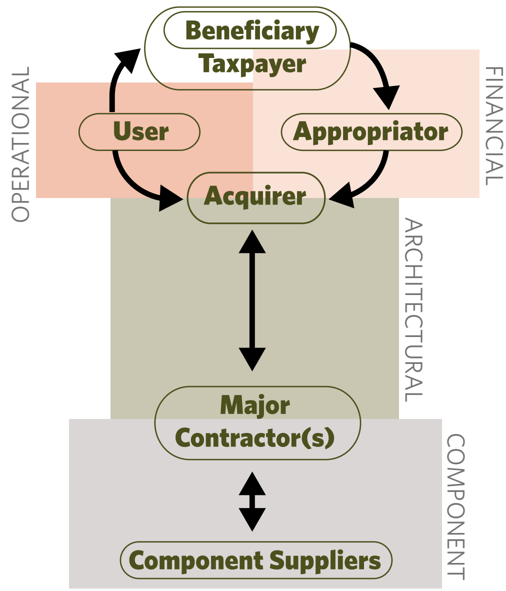
Figure 3 illustrates the differences between the two market types. Since monopsony markets are discrete (i.e., the market only exists when the buyer wants to buy), buyer needs must be revealed explicitly as they arise. If major performance improvements are required of each new acquisition, as is typically the case between generations of spacecraft, radical innovation must occur in discrete intervals, upon request. Since the request for radical change originates from the government buyer, so too does much of the investment in product development for space applications (Sherwin & Isenson, 1967). The market is dominated by a top-down "pull" to the near exclusion of the complementary bottom-up "push." This is a problem because a fertile innovation environment requires the presence of both forces, especially since most new ideas come from outside (Christensen, 2003). Thus, one of the key challenges to innovating in the space market is for the government to encourage bottom-up initiative.

Challenge 2: Representing the Needs of A Disaggregated Buyer

The existence of a top-down acquisition process could theoretically generate ideal conditions for innovation. In a discrete and specific process as previously described, only products that the buyer wants would advance to the development stage. This is ideal, assuming the buyer knows the precise product specifications. However, when the buyer is a monopsonist as complex as the U.S. Government, incorporating multiple disaggregated interests, this assumption may be invalid.

As illustrated in Figure 4, in the government acquisition context the monopsonist buyer—which encompasses the warfighter, the appropriator, acquirer, and taxpayer—is not a single coherent decision maker. The monopsonist exists to centralize both resources and expertise. As a result, since the acquirers (who do the actual choosing) must integrate **operational** (warfighter's expertise) and **financial** (appropriator's knowledge and taxpayer resources) trades to determine what next to buy, the decision will only be as good as their imperfect information. Therefore, unless buyer needs are well represented, delivery only of the product specified in the request for proposal may not be efficient at all.

FIGURE 4. OVERLAY OF KNOWLEDGE AREAS ON SPACE ACQUISITION MARKET STRUCTURE



Challenge 3: Integrating Fragmented Sell-Side Knowledge from the Top-Down

In addition to knowing what it wants, efficiency in a top-down acquisition process also requires that the buyer knows what is possible. In a commercial setting, typically a range of products exists from which to choose. Even when buying for a third party, a history of revealed preferences vis-à-vis similar products provides a reasonable basis upon which to make selections. However, in the case of acquirers buying for warfighters, the acquirers have only ever seen the warfighters use other systems that were also bought for them. While this intensifies the acquirers' challenge, it also presents a unique opportunity for the monopsony buyer (as a whole) to take a long-term, coherent perspective on driving innovation to their benefit.

However, knowing what is possible is particularly difficult in the realm of complex engineering products because they require the integration of so many different types of knowledge. For example, a *simple* communication satellite requires the technical expertise of thermal, power, solar, control, software, structural, and electrical engineers among others. In the time between successive acquisitions (often 10–20 years), advances will have likely been made in each discipline, as well as at the system level. In order to manage this complexity, prime contractors whose primary expertise is systems integration (i.e., architectural knowledge of how the pieces fit together) have emerged. They bid for whole contracts and farm out much of the subsystem development effort (component knowledge). This has led to a hierarchical fragmentation of the knowledge required to know what *should* come next and generate radical innovation (Henderson & Clark, 1990). The result, as shown in Figure 4, is that acquirers are not in a strong position to make this determination; sell-side input is needed.

Challenge 4: Matching the Innovation Environment to the Stage of Development

Utterback and Abernathy (Utterback, 1994; Utterback & Abernathy, 1975) have shown empirically that a relationship exists between maturity of the product undergoing innovation and characteristics of the organization in which the innovation occurred. Dividing the innovation process into three phases—fluid, transitional, and specific—they argue that free experimentation and a diversity of ideas are important ingredients for the fluid phase (e.g., inventors working out of their garages), while increasingly rigid organizational processes become appropriate as the product matures (e.g., a promising idea gets bought out and commercialized by a larger firm). The differences between the organizational environments are summarized in Table 1.

Having multiple, different innovation environments is particularly important for space systems because of their inherent complexity. Space systems decompose into subsystem elements, which decompose into component elements, etc. At each level of integration, innovation can be achieved through improvements to the element itself, or the way in which it interacts with other elements. Both types of innovation are required to achieve radical change, as illustrated in Table 1 (Utterback, 1994). Thus, in addition to the fluid, transitional, and specific phases defined by Utterback and Abernathy, spacecraft development may require additional variants to deal with both the component and architectural dimensions of innovation[2] (Sauser, Ramirez-Marquez, Magnaye, & Tan, 2008). Yet, since spacecraft are developed as a single project, a single organizational environment exists throughout the formal process. As a result, a key challenge involves creating an organization that supports multiple innovation environments simultaneously.

Challenge 5: Balancing Risk Aversion and the Need for Experimentation

Perhaps the biggest difference among the three phases is the extent to which innovation can be planned. Once a dominant design emerges (in the transitional phase), innovation can be achieved by systematically making incremental improvements along particular dimensions, but until that point, there is much less certainty about what will work. In the transitional and specific phase, increasingly formal organizational structures are put in place, and those structures facilitate the optimization aspect of the innovation process. Conversely, the fluid phase start-ups have very little in the way of organizational structure, in part because no consensus has yet emerged on how the creativity is best encouraged (Fagerberg, Mowery, & Nelson, 2005). Another reason is that many innovations fail to make it out of the fluid phase. Most successful entrepreneurs failed several times before they succeeded, and fail again many times afterward. These are not risks that big companies typically take; such bold risk taking requires an undying belief in one's product that is often associated with entrepreneurs (Casson, Yeung, Basu, & Wadeson, 2006). As a result, society does not have a high expectation for the success of start-ups, and their failure is not remarkable. This is not the case for space systems.

Despite the fact that many new spacecraft are, for all intents and purposes, prototypes (i.e., inventions) at the system level, a high level of risk aversion characterizes the U.S. space architecture. Many reasons are cited for the conservatism that exists in the sys-

TABLE 1. RELATIONSHIP OF ORGANIZATIONAL STRUCTURE TO PRODUCT MATURITY

	1	2	3	4	5
Challenge	**Generating bottom-up innovation**	**Representing the needs of a disaggregated buyer**	**Integrating fragmented sell-side knowledge**	**Matching innovation environment to stage of development**	**Balancing risk aversion and experimentation**
Guidelines for improvement	Generate sell-side **initiative**, not just capabilities development	Increase emphasis on flowing needs to requirements	Create more opportunities for interaction through frequent acquisitions	Create additional organizational tiers spanning both the dimensions of product hierarchy and maturity	Shelter advanced spacecraft from failure-is-not-an-option mentality

tem. Unlike most terrestrial systems, once a spacecraft is launched, if systems fail or problems arise, fixing them is extremely difficult. Additionally, the act of launching the system, which is the only way to really test its survivability in the harsh environment of space, is extremely expensive. Thus, an extremely high premium is placed on getting it right the first time. In part because spacecraft tend to be so expensive, failure is accompanied by a high political cost. Unlike in the fluid phase of traditional markets, where inventors receive little attention until they succeed, space projects are highly visible. What's more, the public has little appreciation for the experimental nature of most first flights, reinforcing the need to succeed the first time. However, if innovators are to continue surfacing and developing radically different solutions, the need to shelter them from the constraining pressures of success becomes an imperative.

DoD Approach to Addressing the Challenges of Spacecraft Innovation

Although the DoD acquisition framework was not explicitly designed to address the five challenges previously presented herein, it does address each to some degree. This section describes the nature of the interaction.

Challenge 1: The Challenge of Generating Bottom-up Push in a Top-down Structure is Addressed Directly

The DoD acquisition process employs a two-tiered organizational structure focused on (a) research and development, and (b) formal acquisition programs. Initial technology development within the DoD is conducted by the Service Laboratories (e.g., Air Force Research Laboratory, Naval Research Laboratory, Army Research Laboratory) and several science and technology organizations such as the Air Force Office of Scientific Research, the Office of Naval Research, and the Defense Advanced Research Projects Agency. The technology development tier ensures that capabilities that will be needed in the future are under development today. The approach is relatively successful in generating new technologies, but is limited in two important ways. First, it places a disproportionately high cost and risk burden on the government since it is still an internal organization writing the specifications. Second, a manufactured push (as is the case here) is not the same as a true bottom-up push. Where the latter embodies the results of multiple organizations competing with each other to find the best solution, the former remains a response to a request for progress on a particular technology.

Challenge 2: The Challenge of Representing the Needs of a Disaggregated Buyer is Nominally Addressed Through the Functions of the Joint Capabilities and Integration Development System (JCIDS) Process

JCIDS constitutes the formal DoD procedure for the establishment of acquisition requirements and evaluation criteria for future defense programs, and aims to assess all available alternatives for meeting a validated warfighting need. In so doing, JCIDS seeks to integrate the preferences of multiple stakeholders in the defense establishment by examining perceived capability shortfalls or gaps of the combatant commanders or Secretary of Defense. In theory, JCIDS should address the challenge identified as Challenge 2 exactly; but, in practice the complexity of integrating the needs of such a disaggregated buyer as the U.S. Government leads to significant shortcomings in practice. While the DoD has significant experience translating requirements into products, the department is less effective at flowing needs into requirements—the crux of Challenge 2.

Challenge 3: The Challenge of Integrating Fragmented Sell-side Knowledge has Been Addressed Differently Over the History of the Space Age

Initially, significant in-house technical expertise was cultivated among government buyers, and significant oversight spanning the entire sell-side supply-chain was common practice. The government buyer adopted the risk through cost-plus contracts but retained design authority, thus giving them the ability to intervene when contracts were not being executed as desired. More recently, as cost control became a primary focus, the role of system integrator has been delegated to industry contractors, with technical development subsequently delegated to subcontractors. The idea was that profit-maximizing firms will allocate resources more efficiently. However, in practice the interests of industry do not always align with those of the government, limiting the effectiveness of the relationship. Coupled with the fact that the delegation of the oversight role has led to a decrease in the technical competency of the acquisition corps (NRC, 2008), this trend has exacerbated the challenge of integrating sell-side knowledge rather than helped.

Challenge 4: The Challenge of Matching the Innovation Environment to Stage of Development is Partially Addressed by the Two-tiered Acquisition Structure, in that Technology Development is Separated from Formal Acquisition

As illustrated in Table 2, this separation of the product development into only two phases makes sense if technology development

TABLE 2. RELATIONSHIP OF ORGANIZATIONAL STRUCTURE TO PRODUCT MATURITY

	Fluid	Transitional	Specific
Innovation Characteristics	Product changes/radical innovations	Major process changes, architectural innovation	Incremental innovations, improvements in quality
Organizational Characteristics	Entrepreneurial, organic structure	More formal structure with task groups	Traditional hierarchical organization
Process Characteristics	Flexible and inefficient	More rigid and changes occur in large steps	Efficient, capital-intensive, and rigid

Product Maturity ········›

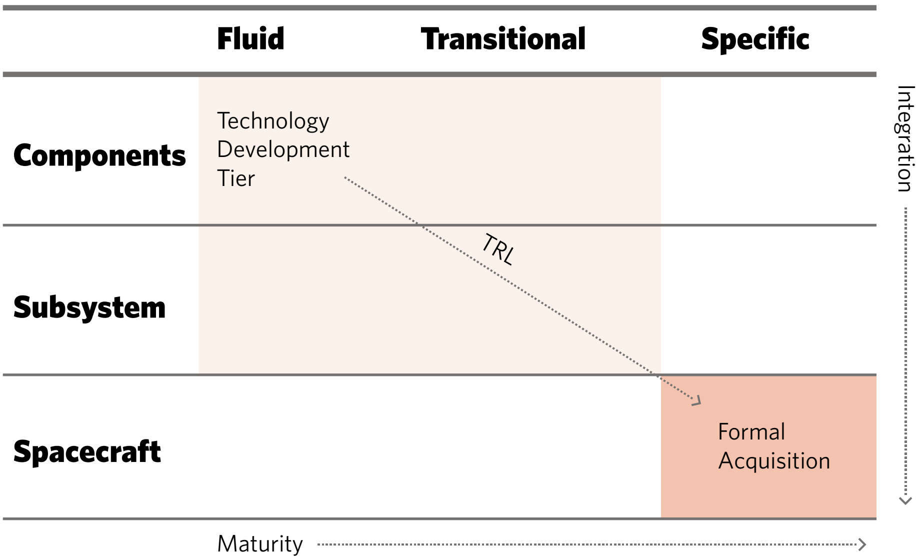
at the component and subsystem levels may proceed linearly to spacecraft-level system integration. However, as discussed previously, TRL is only one component of product maturity. Product maturity is also driven by architectural knowledge that may be measured by a system's readiness for integration. Developing new technologies for components and subsystems may actually *decrease* product maturity because of its ability to modify architectural knowledge of the system. Table 3 presents a more realistic representation of the evolution of product maturity. While formal technology development processes mature technologies in the fluid phase up to the subsystem level of integration, only at the spacecraft level is integration of the constituent technologies addressed. In other words, the formal acquisition process (which has the organizational characteristics of the specific phase) is forced to develop and integrate technologies that are far from specific in terms of maturity.

Challenge 5: The Challenge of Balancing Risk Aversion and the Need for Experimentation Faces a Similar Partial Fix

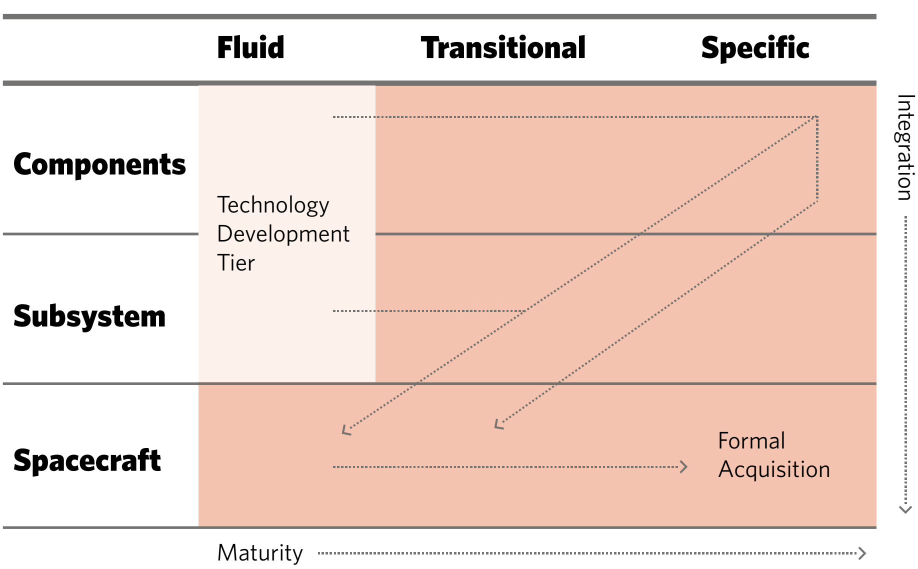
While the technology development tier serves to shelter R&D and component maturation from the public eye, no such shelter currently exists for the whole space system.

TABLE 3. TECHNOLOGY DEVELOPMENT PATHS

a.) Theoretical Two-Tiered Progression



b.) Implementation of Two Tiers



Guidelines for Improving Innovation in the Spacecraft Acquisition System

Over the last decade, multiple blue-ribbon panels have been convened to address known problems with the acquisition system. The key insights from these reviews are summarized in Figure 1. Building on the recommendations therein, this section highlights improvements that would specifically address the five core challenges to space sector innovation, as identified previously. These recommendations are summarized in Table 3.

From an innovation theory point of view, in Challenge 1—generating bottom-up innovation—the space market structure inhibits half of the natural competitive market innovation dynamic. As a result, until more buyers become involved in the space market,[3] any acquisition system will need a mechanism through which to ensure that new ideas continue to be infused into the acquisition system. Development contracts do accomplish this *capability development* to a certain extent, but as discussed previously, they are limited in their ability to encourage *sell-side initiative* and the parallel and varied concept explorations it embodies. Several other models exist for encouraging and leveraging sell-side initiative including commercial off-the-shelf, seed-funding models being explored by the Operationally Responsive Space program office and prizes (e.g., Ansari X-Prize). The idea in each of these is to help sustain a market rather than subsidize the development of a particular technology (i.e., generate sell-side initiative, not just capability development).

With regard to Challenge 2 (needs representation) and Challenge 3 (knowledge integration), the blue ribbon panels are almost unanimous in their recommendations to increase the technical competence of the Defense Acquisition Workforce and emphasize the importance of front-end specification. However, this only addresses half of the problem. No matter how many new capabilities are generated, their value will hinge on how well the original need was represented as a set of requirements. For the other half of the problem to be fully resolved, more emphasis must be given to the challenge of knowledge integration on both the buy- and sell-side. Specifically, with respect to Challenge 2, increased emphasis must be placed on flowing needs to requirements. This will involve a combined effort to educate users about their choices (what is possible) and help acquirers capture their needs more effectively. To this end, value-based system analysis methodologies to facilitate the process of capturing both articulated and unarticulated needs, early in the conceptual design phase, are currently being developed by researchers. Taking the value-centric perspective during conceptual design empowers stakeholders to rigorously evaluate and to compare different system requirements in the technical domain using a unifying set of attributes in the value domain (Mathieu & Weigel, 2005; Ross, Hastings, Warmkessel, & Diller, 2004). If deployed by system program offices, these emerging system analysis methodologies will contribute significantly to overcoming Challenge 2.

Overcoming Challenge 3 will require more frequent interactions among contractors, integrators, and the government through formal acquisitions. Where need-capability information is transferred continuously from buyers to sellers and vice versa, in traditional markets the transfer only happens during contracted hardware development in the space sector. As long as space acquisition continues to operate on a model of infrequent, extremely complex

monoliths, the knowledge required to innovate will continue to be fragmented across the various players. Decreasing the acquisition cycle time will not only help the knowledge integration problem identified in Challenge 3, but also the risk aversion in Challenge 5.

Challenge 4 (matching) identifies a fundamental limitation of the current system. In the existing acquisition paradigm, the product development required to enable future missions is conceptualized as a linear progression from TRL 1–9. With this view in mind, the blue ribbon panels call for increased funding for technology testing. However, while increased funding for technology development is a needed step in the right direction, it only addresses part of the problem. It fails to appreciate the difference between architectural and component dimensions of knowledge and what that means for system-level maturity. If the rest of the problem is to be addressed, a need arises for more than two organizational tiers: one for each of the three phases, as well as the dimensions of component and architectural knowledge.

Similarly, the recommendations of the blue ribbon panels that pertain to Challenge 5 (risk shelter) emphasize a back-to-basics philosophy, which keeps R&D separate from system acquisition. This would serve to shelter component development from political pressures, but do nothing at the spacecraft level. For spacecraft-level development to receive the risk shelter that is required, a major philosophical shift is needed. In this case, a back-to-basics philosophy might mean a return to the CORONA paradigm (e.g., recall that 12 launches of the revolutionary CORONA photoreconnaissance satellite were required before a successful demonstration of film capsule recovery on the 13th flight [Wheelon, 1995]). In other words, if radical innovation is desired, advanced spacecraft technology must be sheltered from the ubiquitous failure-is-not-an-option mentality.

The challenges identified in this article are fundamental to generating innovation in the space sector; they will not be easily overcome. This detailed discussion of the challenges presented in this article provides some guidelines for how to approach solving their associated problems, and will require all stakeholders involved to come together to implement a solution.

Author Biographies

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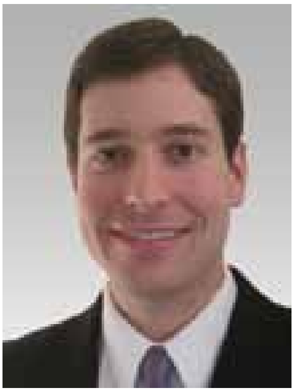

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ENDNOTES

1. For purposes of this article, innovation is defined as a measure of how performance, normalized by resource constraints, changes over time. This can involve either (a) generating a wholly new capability, or (b) reducing the resources required to achieve an existing capability (e.g., making the system cheaper or lighter).
2. While component innovation is achieved through technology development and measured by technology readiness levels (TRL), architectural innovation may not be explicitly addressed by organizations. To support the formal specification of product maturity as a function of both component and architectural knowledge, Sauser et al. (2008) have proposed that a system readiness level be used based on both TRL and an integration readiness level (IRL).
3. This has happened, to a certain extent, in the domain of communication satellites and earth imaging and may soon be the case if space tourism were to take off, but is arguably unrealistic in the near future for more advanced and military applications.

COST GROWTH IN MAJOR DEFENSE ACQUISITION: IS THERE A PROBLEM? IS THERE A SOLUTION?

William D. O'Neil

Cost growth in defense acquisition is both a problem in its own right and part of the larger phenomenon of programs that fail to perform as intended or desired. It is a limited but persistent phenomenon, which has not improved in any material respect over at least the past four decades; nor is it unique to defense, and it can flow from a variety of causes. A limited group of similar remedies have repeatedly been tried, but achieved very little success due to lack of clear analysis of underlying causes. Research points to a corrective technique, "taking the outside view," or "reference class forecasting," with clear promise for attacking the root problems.

Keywords: *Cost Growth, Program Risk, Cost Sharing, Joint Programs, Cost and Analysis Improvement Group (CAIG)*

image designed by Tia Gray »

The reasons for concern about cost growth in terms of its influence on Department of Defense (DoD) programs were succinctly reviewed by Mark F. Cancian (2010). In this article, I address cost growth in defense acquisition both as a problem in its own right and as a part of the larger phenomenon of programs that fail to perform as intended or desired. I show in turn that: (a) it is a limited but persistent phenomenon, which has not improved in any material respect over at least the past four decades; (b) it is not unique to defense; (c) cost growth may flow from a variety of causes—including errors in the management or contracting process—but defects in the original concept are a very common cause; (d) a limited group of similar remedies have repeatedly been tried but achieved very little success due to lack of clear analysis of underlying causes; and (e) research by social and management scientists points to a corrective technique, "taking the outside view" or "reference class forecasting," which has a sound theoretical basis and a limited but significant record of success in nondefense applications as well as specific defense areas. I conclude that reference class forecasting and its supporting analysis and data collection bases should be more widely adopted in defense acquisition, and particularly in early evaluation and delineation of technical issues.

A Limited, But Persistent Problem

In the United States, the modern era of concern about defense program cost and results can fairly be said to have started in the late 1960s and early 1970s. Congress began demanding Selected Acquisition Reports (SARs) to provide much better and more comprehensive reporting of the costs of Major Defense Acquisition Programs (MDAPs) (Cancian, 2010). DoD instituted reforms, including establishment of the Cost Analysis Improvement Group (CAIG) (Srull, 1998, pp. 5–17), presently a statutory constituent of the Cost and Program Evaluation Office.

Congress has repeatedly revised the laws governing MDAPs, while DoD has gone through more than a dozen substantively different generations of its 5000-series acquisition regulations since the first versions were issued in July 1971 (Ferrara, 1996). The Obama Administration followed its predecessors in instituting a spectrum of reforms and initiatives aimed at acquisition improvement, while one of the incoming president's early acts was to sign into law a new Weapon Systems Acquisition Reform Act of 2009, Pub. L. 111-23.

The Statistical Record of Cost Growth in DoD

Examination of successive annual SARs shows that when significant cost growth does occur, its full magnitude rarely is apparent for several years following program initiation, and frequently not for 10 years or more—even leaving aside growth from increased ultimate production quantities. Thus, it will be years before the real results of these new initiatives can be objectively assessed. Indeed, assessments are difficult to make well or even long after the fact. But the best and most comprehensive assessment of MDAP cost growth to date has concluded that up through programs that started officially as late as the mid-1990s, none of the reforms since the first batch in the early 1970s had any major overall effect in reducing cost growth. A study authored by Dr. David L. McNicol (2005, pp. 18–19), former chairman of the CAIG, now with the Institute for Defense Analyses (IDA), deals principally with procurement, with very limited detail on development. While the study does not include more recent results that might reflect reforms undertaken early in the 2000s, I will show that limited data do not give any indications of improvement.

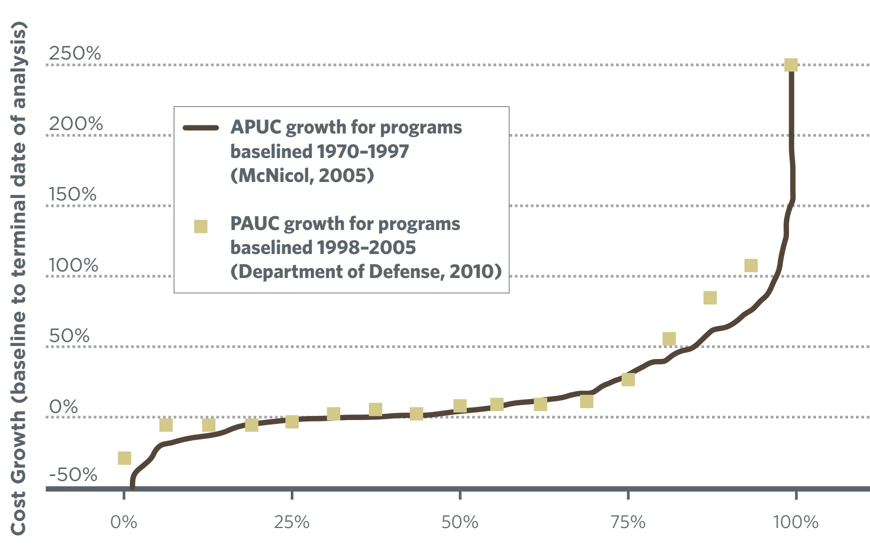
This is only one of a number of analyses that attempt to determine trends in defense acquisition cost growth. Others of relatively recent date (Arena, Leonard, Murray, & Younossi, 2006; Christensen, Searle, & Vickery, 1999; Sipple, White, & Greiner, 2004; Smirnoff & Hicks, 2008) employ various statistical techniques, but all work from the historical SAR database extending back to December 1969, with its many analytical pitfalls. Hough (1992) identified the most notable problems as: (a) failure of some programs to use a consistent baseline cost estimate, (b) exclusion of some significant elements of cost, (c) exclusion of certain classes of major programs, (d) constantly changing preparation guidelines, (e) inconsistent interpretation of preparation guidelines across programs, (f) unknown and variable funding levels for program risk, (g) cost sharing in joint programs, and (h) reporting of effects of cost changes rather than their root causes.

McNicol (2005) used a variety of approaches to avoid or mitigate the effects of these pitfalls. He started with data refined by adjusting all values to constant 2000 price levels and constant quantities, pruning entries not really relevant to rigorous and consistent statistical analysis of cost growth, employing a refined categorization of individual cost increases to distinguish meaningful trends, and further adjusting the data to account for decisions to change requirements or budgets. Then he used the standard econometric technique of Ordinary Least Squares Regression analysis of panel data to estimate the magnitude and significance of a wide variety of causative influences on cost growth. While all of the analyses agree that over time no major change in cost growth has resulted from numerous reform efforts, McNicol (2005) best and most rigorously isolated the specifics; accordingly, I largely follow his lead in analysis of causes.

One other major study has examined the SAR data with similar care to provide clear insight into root causes (Bolten, Lenonard, Arena, Younossi, & Sollinger, 2008), but it limits its scope to fewer than one-third as many programs as McNicol (2005) covered, making McNicol's the superior choice for purposes of this study.

After pruning, McNicol was left with 138 MDAPs that passed their Milestone II or Milestone B (marking formal approval as programs and entry into engineering and manufacturing development [EMD], and approval of a baseline cost estimate) between the beginning of 1970 and the end of 1997. At the most summary level, his data are plotted in the Figure as the solid line showing the distribution of average procurement unit cost (APUC) variance from baseline estimate. While few programs exactly met their initial procurement cost estimates, three-quarters of them came reasonably close. It is the smaller number of very high growth programs, representing roughly one quarter of the whole, which contributed the great bulk of overall cost growth.

FIGURE. PROCUREMENT UNIT COST GROWTH OF MDAPs INITIALLY APPROVED BETWEEN 1970 AND 1997, AND PROGRAM UNIT COST GROWTH OF THOSE APPROVED BETWEEN 1998 AND 2006



Extending the Statistical Record

McNicol's (2005, p. 45) data did not extend past the end of 1997. Regrettably, resources to update the data set he currently uses, which would permit reanalysis, have not been forthcoming. Using raw gross data from the most recent SAR summary tables (DoD, 2009a), however, I have calculated the program average unit cost (PAUC) variances for those programs with baselines between 1998 and 2006 and plotted the distribution of these as the series of discrete green squares in the Figure. These points represent only those programs that had their initial development estimates in this period, have nonzero procurement quantity, and have a minimum of 3 years EMD since the initial development estimate—all for the greatest possible consistency with the series from McNicol (2005). The most notable remaining gross-level inconsistency is that the PAUC data include development and military construction costs rather than solely procurement costs as detailed in McNicol (2005), and development costs on the whole are known to show higher cost growth (McNicol 2005, p. 17). But the effect of this is mitigated because, in general, procurement cost outweighs development by 4:1 (McNicol 2005, p. 4).

Clearly, the two distributions plotted in the Figure show the same general character, with that for the more recent period having generally higher growth in the upper quartile. A two-sample, two-tailed Kolmogorov-Smirnov statistical test finds inadequate evidence to accept the hypothesis that the 1998–2006 sample is drawn from the distribution of the 1970–1997 sample even at the 80 percent significance level ($p = 0.638$). Because of the differences in the two data sets, we must not read too much into this result, but clearly the statistical test reveals no evidence that even hints of secular improvement in control of cost growth, at least through 2006.

In both the earlier and later samples, we see that roughly three-quarters of the included MDAPs have reasonably satisfactory cost growth histories, with at most no more than 30 percent growth and average growth near zero. Excessive cost growth affects only a minority of programs.

To obtain a statistically consistent sample, the results shown in the Figure put aside programs that are terminated early, that are radically restructured, or that follow significantly nonstandard development paths. Recent examples include the Army Future Combat System and Navy Littoral Combat Ship. Such programs often have high cost growth and thus cannot be neglected in considering effects and cures, but their omission does little to affect the overall statistical picture. Some of the 1990s-era programs shown could well experience further cost growth, since the most seriously troubled programs tend to involve considerable extensions in development. Two notable examples are the 4-year slip in the schedule for completion of the F-35 Joint Strike Fighter EMD (DoD, 2010) and approximately 9-year slip in schedule for the Space Based Infrared Satellite (SBIRS) High (DoD, 2008).

Public discussions of defense cost growth often make it seem like a problem unique to DoD, but this gives a distorted impression that impedes accurate understanding and effective correction. In fact, complex programs throughout government and private industry are very prone to cost growth (Flyvbjerg, Bruzelius, & Rothengatter, 2003; Lovallo & Kahneman, 2003; Merrow, Phillips, & Myers, 1981; *New York Times*, 2011).

The Futility of Relying on Price Competition

Every incoming DoD administration has made efforts to improve the management of acquisition, with control of cost growth usually a prominent declared objective. But to a very great extent, lack of accurate diagnosis of causes has undermined these initiatives. Notably, a review of a pair of foundational studies of defense acquisition performed half a century ago by Merton J. Peck and Frederic M. Scherer of the Harvard Business School reveals significant issues still largely unaddressed by intervening management efforts (Peck & Scherer, 1962; Scherer, 1964). In particular, Peck and Scherer (1962) argued at length that price competition—a wide favorite for controlling costs—is bound to be largely ineffective in major defense system acquisition, and very likely counterproductive.

Nevertheless, officials have repeatedly emphasized price competition in acquisition. They have advocated price competition under a variety of banners, with the common element being an attempt to include a firm commitment regarding production of at least the initial lots as an important element in selecting the development contractor, thus transferring the risk of cost growth to the contractor.

In principle this seems sound and businesslike. Cases exist where it has seemed to work reasonably well, but only in limited circumstances. The six cases of this approach that were covered in McNicol (2005) all had especially high cost growth, putting them in the upper quartile, as shown in the Figure. A more recent example is the SBIRS High, which attempted a modified version of this strategy. SBIRS High has suffered especially great cost growth (DoD, 2010), with more than 175 percent reported.

Attempts to transfer the risks of cost growth to the contractors fail in much the same way that the nation's banking system collapsed in 2008, and for broadly parallel reasons. Even though the remaining major defense contractors are at little risk of being allowed to go out of business, the fortunes of their individual business units can fluctuate a great deal. Their managers can and fairly frequently do suffer diminished career prospects and even job loss when things go wrong—a powerful negative motivation. But they face a painful dilemma. If they promise too much, then they may come to regret it in a few years. Yet, if they promise too little, they will lose out at once to a competitor. In such circumstances, the incentives weigh heavily on the side of accepting future risks rather than immediate ones, for one can always hope for some redemptive development in the meantime.

The critical faculties of the corporate leaders who must ultimately approve the offer are blunted by the knowledge that they command an organization too big and vital to be allowed to fail. A program filled with problems may cause pain, but not corporate destruction. And like their subordinate business unit managers, they may well hope for some future deliverance.

No plausible threats of retribution for distant problems, however dire, can go far to offset these mechanisms. In principle the government can reject offers deemed unrealistic, as it does when offerors omit some significant element or make a demonstrable error. But a source selection authority (SSA) cannot simply substitute his or her own judgment for the contractor's regarding prospective improvement or advances in development or production. Even at best, attempting to distinguish degrees of realism among competing proposals, in many cases, is fraught with unforeseen difficulties.

If the contractor is to be held responsible, the government must allow it much autonomy and authority. In programs where price competition is not central, the government may step in and provide essential assistance and direction when a contractor encounters difficult problems, but this is inconsistent with holding the contractor responsible. Individual case studies of such programs often show contractors running into trouble while responsible officials hesitate to intervene. Most detailed case studies contain sensitive information and remain unpublished, but this effect can be clearly seen in Whittle (2010) and Younossi et al. (2008).

Other Inadequate Explanations and Solutions

Sometimes problems may be solved, or at least improved, without thoroughly analyzing their causes. After four decades of failed attempts, however, we have to question how long it might take to make much progress against cost growth and its companion problems through cut-and-try.

Some usual suspects can be dismissed from the lineup at once on the basis of strong alibis. These include:

Profiteering. Defense contractors are not noted for high profit rates, and executive compensation is not a major expense in this industry.

From the government's perspective, the function of profits is to permit industry to raise the capital it needs to serve government needs. Contracting policy is shaped in various ways to minimize the levels of profits necessary, and analysis shows that in general this is achieved efficiently. Profitability could not be significantly lower without impairing industry's ability to meet government needs (Arnold, 2008, pp. 13–15).

Lack of incentives to economize or reduce inefficiency. Throughout the history of American defense contracting, concerns have repeatedly been expressed that in the absence of immediate and direct competitive pressures at every stage, firms would lack incentives to economize (Holley, 1964). Close analysis by Arnold, McNicol, and Fasana (2009), however, showed that on the whole, government contracting officers make quite effective use of legally permitted contract incentives to motivate performance.

Experience in working within or close to defense industry firms and government acquisition organizations reveals many areas of apparent inefficiency or waste—ill-motivated or poorly qualified personnel, idle resources, deteriorated equipment, bureaucratic busywork, minor peculation, and a host of others. Yet on the whole, the experience is not noticeably different in nondefense industry. Where it has been possible to make more or less direct comparisons, they have revealed no systematic deficiency in defense-related efficiency (Besselman, Arora, & Larkey, 2000; Kelley & Watkins, 1998). The pattern in which a relatively small proportion of programs account for virtually all of MDAP cost growth cannot be explained by industry inefficiencies unless they are somehow specific to particular programs.

Requirements creep. Requirements changes do occur and they contribute to cost growth. But the cost data set used by McNicol (2005) adjusted for requirements changes; thus, they did not contribute to the pattern of cost growth seen in the Figure.

Technology risk. Another usual suspect is in fact more commonly implicated in major cost growth: excessive technology risk. Public Law 111-84 (Armed Forces, 2009) requires certification at the time of program initiation that "the technology in the program has been demonstrated in a relevant environment." This corresponds to what the Department of Defense (2009b) defined as Technology Readiness Level Six (TRL 6). The Government Accountability Office (GAO), in its periodic assessments, regularly emphasizes technology readiness, which it cites as a major factor in determining the prevalence and seriousness of cost growth. Levels of technology maturity at program initiation have been rising in recent years, which the GAO sees as an encouraging sign for future control of cost growth (GAO, 2009, pp. 16–17).

But cost growth is by no means consistently a result of low technology maturity. The Expeditionary Fighting Vehicle (EFV) program is a notable example. More than a quarter of a century of focused technology development efforts preceded program approval in 2000, including the construction of a series of functional prototype vehicles. All but one of the program's critical technologies met TRL 6, and the remaining one has not caused prohibitively expensive problems. Nevertheless, the engineering prototypes functioned so badly that testing had to be abandoned, and EMD had to be started over again. Planned procurement has been cut more than 43 percent, objectives for performance and reliability have been scaled back substantially, scheduled initial operational capability has been slipped by approximately 9 years, and the estimate of APUC has risen by 168 percent (DoD, 2008).

In the EFV as in many other high-growth programs, the fundamental problem is not technology per se but failure to work out and recognize in advance many of the implications of the design choices that were made at the time of program initiation. We can trace a high proportion of the problems in the current and former "leaders" in cost growth to variations on this theme. Program managers and engineers laid confident plans to achieve performance and schedule goals without recognizing what they truly involved. This can be clearly seen in a few published program case studies (Coulam, 1977; Whittle, 2010; & Younossi et al., 2008), but other studies remain unpublished due to sensitivity.

The Origins of Flawed Plans

How can this be? How can experienced and well-qualified managers and engineers repeatedly fail to lay realistic plans? How can acquisition officials repeatedly overlook such faults, often bending or setting aside established policies to do so? Modern research in social and management sciences provides answers, involving patterns of behavior at both the individual and group level.

At the individual level, the key factor is the *planning fallacy*. This is a concept growing out of the work of Daniel Kahneman and Amos Tversky (1977, 1982). The phrase refers to the pervasive human tendency to hold "the conviction that a current project will go as well as planned even though most projects from a relevant comparison set have failed to fulfill their planned outcomes." Controlled experiments have repeatedly validated the phenomenon (Buehler, Griffin, & Peetz, 2010).

Management and social scientists have explored the planning fallacy's operations and implications specifically in business (Lovallo & Kahneman, 2003; Flyvbjerg, Lovallo, & Kahneman, 2003) and major infrastructure projects (Flyvbjerg, Garbuio, & Lovallo, 2009). Many of the problems they found in particular cases traced to faulty decisions related to the planning fallacy (Buehler, Griffin, & Peetz, 2010).

At the group level, the scenario these studies present as typical involves individuals and groups competing to secure adoption of their proposals for a new program. They are driven to making unrealistic promises, in exactly the same manner—as I have already argued—indicative of firms competing for contracts. That is, the groups that make the most optimistic promises gain an advantage, so long as their optimism does not excite outright incredulity. Their optimism is fostered by their own planning fallacies, and once decision makers have bought into a proposed program, they too are drawn into planning fallacy.

Explicit strategic deception may possibly be involved at one level or another, deliberately calculated to gain advantage over competing proposals (Flyvbjerg, Holm, & Buhl, 2002; LaBerge, 1982). But very unrealistic plans can come into being and gain approval without Machiavellian calculation, particularly in a cascade of multiple levels of decision with associated multiple layers of planning fallacy. In defense acquisition, my experience suggests that this is far more common than calculated deception.

The planning fallacy appears to be a given fact of the innate workings of human thought. It is extremely difficult to see it in ourselves, and the practically minded people who predominate in decisions regarding acquisition programs seem particularly resistant to such introspection. But we can see it outside of ourselves, if we are able to look dispassionately, and that offers an important clue about what might be done to mitigate its ill effects (Buehler et al., 2010).

Kahneman and his colleagues suggest what they call *taking the outside view*, or *reference class forecasting*, founded in a process of analyzing data from the results of prior programs or efforts that correspond closely—as closely as possible—to what is planned. Even though the correspondence is not exact, this procedure provides a more reliable guide to results than forecasting directly on the basis of detailed program plans (Flyvbjerg, 2008).

The Role of the CAIG

This sounds much like what the CAIG has been doing in a sophisticated and rigorous way for the past four decades, using what it terms the *parametric method.* As the CAIG's first director described it, "The parametric approach does not rely on a detailed description of the 'inputs' to the system, but rather considers system 'output' characteristics such as speed, thrust, etc. Historical defense system cost experience is used to develop relationships between such output characteristics and system costs. These empirical relationships are then used to project a portion or all of the costs of a new system" (Srull, 1972).

In some cases, the CAIG may make early estimates using analogies with generally similar systems, but there too it seeks rigor through the use of structured and objectively evaluated selection of analogues. In either event, it is pursuing the "outside view," as Tversky and Kahneman, and those who have followed them, have recommended (Buehler et al., 2010; Flyvbjerg, 2008).

Establishment of the CAIG was followed by a large, swift improvement in agreement between official estimates and actual costs, even though acquisition officials were not required to accept its recommendations and only rarely did in full (McNicol, 2005). Viewed from outside the CAIG, it seemed clear to me at the time that the knowledge that estimates were reviewed led to increased attention to cost estimating by program managers and the sponsoring organizations, and increased willingness to adopt the CAIG's parametric methods. This was fostered by its active efforts to share its data and methods. Thus, the CAIG brought a measure of cooperative-competitive synergy to cost estimation.

Effective Measures

Impressive as it is, the record of the CAIG (and of its methods in other hands) has limitations. DoD treats CAIG estimates as sensitive management information and does not release them, but based on seeing many over the past four decades, it seems clear to me that they are usually more accurate than (and higher than) the Service estimates, but also sometimes significantly inaccurate. Unpublished case histories of some high-growth programs show costs growing well beyond even CAIG forecasts. Even a very intensive examination with full access has failed to find enough relevant data to permit a comprehensive statistical analysis of the CAIG's historical accuracy, but does make it clear that there are incidents of substantial underestimation (McNicol, Tyson, Hiller, Cloud, & Minix, 2006).

Its authors remark:

> The estimates prepared by cost estimators are crucially dependent on technical and programmatic assumptions over which they have little or no say. There are some gray areas; cost estimators should recognize—and provide corrections for in their estimates—some types of unrealistic program assumptions and some likely execution problems. But, without trying to fix the boundaries of these exceptions, it is clear that they are exceptions—cost estimators generally are not equipped to do engineering analyses of proposed programs or to assess the capabilities of potential contractors. (McNicol, 2005, p. 19)

The unpublished case studies suggest this as a very significant cause of serious underestimates. In most of these cases, it was possible to know that the technical assumptions were optimistic, and this was pointed out by at least some observers at the time. While no comprehensive survey has been conducted, in confidential interviews CAIG personnel have told me that in some cases they had reservations, but ultimately lacked a strong basis for questioning confident assertions by program managers or other official advocates. Thus, while no basis exists for assessing the incidence of such situations, we can be sure it is not zero.

This relates to what then-Deputy Secretary of Defense David Packard (1970) emphasized four decades ago: Cost growth is closely related to technical problems including schedule slippage, quality problems, and inability to meet baseline requirements (Flyvbjerg et al., 2003). Faulty initial engineering plans and concepts are not the root of all cost growth, but are involved in much of it.

These problems can be attacked by an approach comparable to that which the CAIG uses—taking an outside view, using reference class forecasting of technical factors as well as the costs that depend on them. The basic techniques for parametric analysis of engineering characteristics are well established and have been used by engineers for at least 250 years in the early design phases of systems of many kinds (Vincenti, 1990, pp. 138–141). They are a great deal like the techniques used by the CAIG in that they do not depend on highly detailed information about the system design or particular technologies. Those who apply them must have appropriate broad technical knowledge and judgment, but do not need deep expertise in the particular systems.

When one examines program development histories closely, as I often have, it becomes apparent that there are cases in which the problems were such that even thorough engineering parametric analysis might not have identified them, but many more in which it should have—if it were tried. Unless and until it is tried in a systematic way by competent personnel, there will be no way to be sure. But given the historical evidence regarding the value of engineering parametric analysis generally, together with the modern evidence regarding the importance of the "outside view," it seems that a thorough trial is called for—and all the more so since the cost of such efforts is so small compared to the costs of even one badly conceived or executed program.

Author Biography

Mr. William D. O'Neil has more than 40 years of experience in defense acquisition, and has held executive acquisition-related positions in the Office of the Secretary of Defense, Lockheed Corporation, and the Center for Naval Analyses (CNA). He is presently a consultant dealing with acquisition issues for the Institute for Defense Analyses as well as a CNA Senior Fellow. He holds degrees from the University of California, Los Angeles, in mathematics and quantitative management science.

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CREATING AND SUSTAINING AN EFFECTIVE GOVERNMENT–DEFENSE INDUSTRY PARTNERSHIP

Steve Mills, Scott Fouse, and Allen Green

U.S. history is replete with enterprises that succeeded due to effective partnerships. Today, the nation's most complex partnership is the joint pursuit of the world's best combat capabilities by the U.S. Department of Defense and the defense industry. These two complex enterprises, on behalf of the nation and its allies, are actively developing, producing, fielding, and sustaining combat systems for joint warfighters that are second to none. Does this shared interaction form an effective partnership? In this article, the authors analyze private industry's perception of the challenges/opportunities that exist in the shared relationships with their government counterparts. Their findings pinpoint five focus areas, with corresponding actions, which can improve the partnership between government and the defense industry.

Keywords: *Partnership, Industry, Program Manager, Request for Proposal (RFP), Request for Information (RFI)*

image designed by Miracle Riese »


partnership
DoD
Industry

In 1803, President Thomas Jefferson was diligently searching for the best qualified individual to lead the first expedition into the wilderness of the recently acquired Louisiana Territory. Defying conventional wisdom, he would eventually choose two complementary leaders.

U.S. Army Captains Meriwether Lewis and William Clark jointly led the *Corps of Discovery* from St. Louis, Missouri, to the Pacific coast of the United States. Both men held many key traits in common. Both possessed strengths the other lacked. Their partnership provided leadership that helped to ensure a successful and comprehensive survey of the land's majesty.

U.S. history is replete with enterprises that succeeded due to effective partnerships. Today, one of the most complex and demanding relationships may be found in the development, production, fielding, and sustainment of combat capabilities to the United States and its allies. The U.S. Department of Defense (DoD) and the defense industry are both engaged in this pursuit, but does this shared interaction form an effective partnership? Several indicators seem to suggest this relationship could be improved. A September 2008 report published by the U.S. Government Accountability Office (GAO) stated:

> To better ensure Warfighter capabilities are delivered when needed and as promised, incentives must encourage a disciplined, knowledge-based approach, and a true partnership with shared goals must be developed among the department, the military services, the Congress, and the defense industry. (GAO, 2008)

Since WWII, the need for a true government–defense industry partnership has been clearly established. The U.S. military's global dominance can be directly attributed to the technological superiority gained through a true partnership between these two complex enterprises. As noted by the Center for Defense Information (CDI) (1987), "It is often forgotten that the miracles of the 'Arsenal of Democracy' were the product of a government-industry partnership" (CDI, p. 36). The phrase "Arsenal of Democracy" was originated by President Franklin D. Roosevelt in December 1940 regarding a promise of assistance to the British and the Russians, then at war with Germany, by providing them with military supplies. The phrase also spoke to the ability of the United States to rapidly convert its automotive manufacturing capability to produce military weapons in great quantity during World War II.

In this article, we provide a discussion on the current state of the shared partnership between the U.S. DoD materiel acquisition management community and the private defense industry. We cite findings from one study and one survey—a study of program managers (PMs) serving in the DoD and a survey of PMs working in private industry. We identify and discuss what we believe to be five important facets to any partnership and what the data suggest about the relationship between the DoD and its industry partners. Finally, we offer recommendations on how to strengthen and improve existing partnerships and advice on how the Defense Acquisition University (DAU) and the Project Management Institute (PMI) can support such efforts.

Current State of the Government–Defense Industry Partnership

Under Secretary of Defense for Acquisition, Technology and Logistics Dr. Ashton Carter recognizes the critical importance of the relationship between the government and private industry counterparts in materiel acquisition programs. He recently commented:

> I have said many times…that I really do believe in the partnership between government, the Department of Defense and the defense industry. The reality is that we don't, in the Government, build the weapons systems upon which our security depends. We contract for them with the private sector, and that creates a situation of partnership. (Carter, 2009)

Dr. Carter's comments underscore the genuine need for a true government–defense industry partnership to exist between government and industry in the execution of defense materiel acquisition programs. However, the results of one study and one survey conducted by the DAU suggest that DoD and the defense industry do not have a strong relationship built on a true sense of partnership. Clearly, the DoD and defense industry must interface, but our research reveals that *something* is clearly lacking.

Office of the Secretary of Defense Study on PM Training and Experience

In July 2009, DAU published the findings from a study commissioned by the Director, Portfolio Systems Acquisition David Ahern, on behalf of the Office of the Secretary of Defense (OSD). The study was based on responses from PMs working in Acquisition Category I and II programs. Its proponents sought to determine if DoD was providing appropriate and relevant instruction to its managers and to identify any opportunities to improve the proficiency of such individuals (DAU, 2009, p. 3). The study included findings in three areas: training topics, training methods, and acquisition experience and careers. The paramount finding listed under the title "Topics of Training" was that "program managers need additional training in industry practices, including factors that motivate contractors and ways in which program managers can use incentives to achieve better program performance for the government customer" (DAU, 2009, Appendix A, p. 13). Given decades of government–defense industry partnership in developing, producing, and fielding warfighter systems, why is this a major area of concern for top-level government PMs? We believe these findings indicate that while government PMs understand the inherent value in creating effective partnerships with industry, the current state of the relationship between these two enterprises is not conducive to the greater levels of understanding and partnership that government PMs desire.

DAU Survey of Defense Industry PMs

In early 2010, DAU conducted a survey of PMs employed by private firms. The purpose was to develop an appreciation for private industry's perception of the challenges and opportunities that exist in the shared relationships with their government counterparts. The DAU approach involved a broad array of PMs from five major defense industry companies. The results provided data regarding the level of genuine partnership that currently exists between DoD and industry PMs. The findings from this survey fell into five broad categories: respect, money, communication, processes, and leadership. These five categories identify what we believe to be the crucial relationship elements necessary for establishing and sustaining any effective and stable partnership, including the shared and mutually beneficial government–defense industry partnership.

Respect

Mutual respect is vital to any successful partnership. While the OSD study of government PMs yielded no concerns in this area, the DAU survey of industry PMs pinpointed respect as a key issue. Many respondents identified what they perceived to be a commonly held attitude among mid-career government employees: Mid-career government employees do not see industry agencies as valued partners. Instead, these government employees see industry as merely uncommitted vendors, motivated only by profit; as a result, industry must be managed harshly (Mills, 2010a). Whether real or perceived, the "we versus they" mindset exists in nearly all activities involving the government and industry, and is a major barrier to successful partnering.

Timing of the release of solicitation documents is another area of concern cited by survey respondents. These government-generated Requests for Information/Requests for Proposal (RFIs/RFPs) are top-priority documents for private defense firms. Each RFI/RFP represents a significant investment of company time, talent, and monetary resources to provide a timely and competitive response. A considerable number of the industry PMs surveyed identified the government's recurring habit of releasing RFPs prior to a major holiday, along with a comparatively short deadline (60 days or less) for proposal submission. While this situation might be required for some programs, the consensus among the industry respondents is that this is an all too common practice. Industry PMs felt that these practices are indicative of the government–defense industry relationship. Moreover, this practice reveals an inconsiderate attitude toward industry partners.

Money

Differing expectations, attitudes, and purposes for money are all potential sources of strife between partners. One senior-level industry PM responded with the following analysis concerning the importance of monetary resources for private industry:

> Industry has three primary concerns when it comes to dollars and cents:
>
> - Acquisitions. This is the deep fight. Future business in the pipeline. This is where our business development process occurs, including capture and positioning for future defense acquisition programs.
> - Sales. This is the current fight. Here we are concerned with Return on Sales and the amount of effort expended over a specified time to deliver the products.
> - Margin. This is the second element of the current fight. We address the question, "How do we drive more profit into the existing product? Margin can be improved through continuous improvement and new technologies to drive down the overall product cost on the products being delivered. (Mills, 2010a)

The manner and efficiency with which industry manages its money and achieves acquisition, sales, and margin determine its ultimate success. The findings from the DAU survey demonstrate that industry PMs believe perspectives regarding money are very different from those of their government counterparts. In general, the survey indicates industry PMs believe government program personnel do not have an appreciation for the real-world dynamics with which private firms contend in their effort to meet acquisition, sales, and margin demands. Industry PMs expressed some specific frustrations such as, "Government does not understand the importance or role of reasonable profit in industry" (Mills, 2010a), and "Government acquisition personnel are generally not aware of the real cost of goods and services provided by industry." One industry respondent noted, "Government has a very shallow understanding of industry and money, overhead rates, wrap rates, fully burdened costs, etc." (Mills, 2010a).

Communication

The ability to communicate effectively at all levels of a partnership is crucial for overall success. Industry respondents provided different assessments of government communication skills. Their major concerns in this area were focused around two primary areas: the poor quality management of government solicitation documents and the instability of customer requirements.

One industry employee interviewed stated, "Government RFPs are most often poorly written. Many are merely cut and paste efforts from earlier RFPs, making them completely inaccurate and unclear" (Mills, 2010a). Another industry employee noted that the "government tends to focus on improvising the RFP writing process. Government expertise in this area is very low" (Mills, 2010a).

Perhaps related to the alleged poor quality of government-issued RFPs are the numerous challenges involving requirements definition and requirements growth—sometimes called requirements "creep." One industry respondent cited this as a particularly bothersome issue saying, "Requirements/scope management and managing changes is the number one challenge/problem for the government" (Mills, 2010a). Many PMs expressed that scope and requirements changes make a direct, negative impact on their company's ability to meet the cost and schedule terms of their contracts with the government. One PM said that the "government has a complete lack of appreciation for the impact/cost of changes to the program scope, budget, and schedule" (Mills, 2010a).

Requirements management challenges have negative effects for both industry and other government agencies. The Office of the Director of Operational Test and Evaluation (DOT&E) stated in its 2009 annual report:

> The department's experience indicates that unless programs start with clear, sensible, and rationalized requirements, the program and its testing suffer tremendously and to the detriment of our fighting forces. The DOT&E experience has been that no amount of testing can compensate or correct for unjustified or unrealistic performance expectations. (Gilmore, 2009, p. iii)

The two primary components of requirements management are defining the requirement and stabilizing the requirement. Both components must be effectively managed to minimize "requirements creep" and achieve favorable program results. DoD can better partner with industry in this area through better leveraging industry's Independent Research and Development (IRAD) efforts. IRAD in industry represents each company's efforts to develop their technology innovation and market discrimination. According to Blakey (2010), this presents a critical opportunity for DoD to shape and leverage technology development and the acquisition process.

> DoD must identify future technology requirements so that industry can plan its IRAD investments. Requirements for new systems must be based on well-understood technologies and stable product rates, to allow industry to develop and build systems efficiently with the right contract type. For example, one company recently consolidated its shipbuilding operations and is considering selling the unit outright in response to its vision of the future business environment. (p. 68)

This approach, when implemented effectively, provides industry with much needed and desired stability. Clearly defined and stable requirements remain critical to program success.

Processes

Another important facet in establishing effective partnerships is an understanding of and deference to the key processes of one's partner. As cited earlier, government PMs acknowledge the benefit of better understanding industry practices and processes. Likewise, industry PMs interviewed identified a need for an improved understanding of government materiel acquisition management processes. "Industry," one respondent said, "needs to better understand the government [DoD Instruction] 5000.02 processes in order to work more effectively with the government" (Mills, 2010a). Another industry PM provided this insight:

> Some companies have strong PM culture and PM training programs. Industry standard credentials [PMI Project Management Professional, for example] bring PM skills to the table, but industry needs to understand the DoDI 5000.02 process in order to work more effectively with government. (Mills, 2010a, p.6)

Industry PMs strongly believe that mutual training opportunities represent the best avenue to better understand and improve the shared processes of government and industry. Specifically, some respondents noted that DAU courses have the ability to overcome the shortcomings of both government and industry in understanding the acquisition process.

What prevents reciprocal training among employees of the government and the defense industry? One challenge is that industry often does not incentivize personnel to attend classes because career progression is not tied to the training and experience afforded by government courses. Classes of this type are usually deducted from the company's "overhead" funds, which are generally very limited. Finally, government acquisition personnel have priority for admittance in government courses, thus limiting the ability of private employees to participate. This is especially important in light of the increased Defense Acquisition Workforce employee population projected for the near- to mid-term.

Leadership

Leadership is the most crucial component needed for establishing effective partnerships. Leadership can be described as the art of influencing people. Leadership is necessary for the application and management of all essential facets for the creation of genuine partnerships.

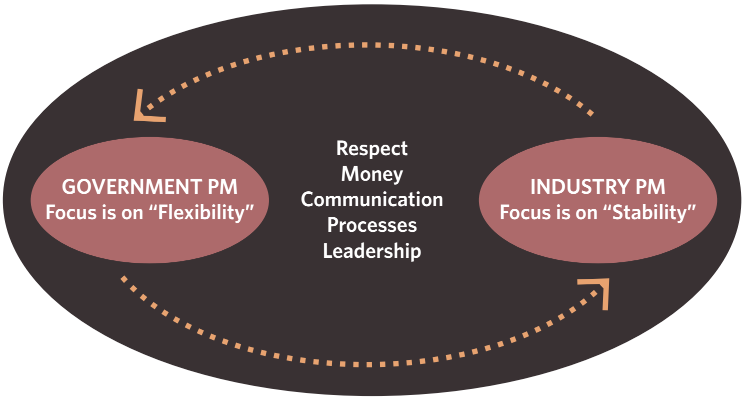
Respondents to both the OSD study and the DAU survey identified leadership as a key focus area. According to the OSD study, in the areas of acquisition, experience, and careers, "PMs need mentors and senior advisory teams to assist them in dealing with particularly complex challenges on major acquisition problems" (DAU, 2009, p. 24). In this area, one government PM stated specifically, "The best preparation for a future program manager is working with extraordinary leaders–mentors" (DAU, 2009, p. 24).

In the DAU survey of industry PMs, respondents stated that the government leadership at the executive levels was sound, but they expressed concern about junior employees. "Although the PM leadership and competency tends to be good, this is not so at the lower levels" (Mills, 2010a). Interestingly, industry PMs perceive a cultural shift occurring within the government acquisition community. One PM observed "a younger, more aggressive crowd that lacks understanding and experience [is emerging] in acquisition. For these younger personnel, failure is frightening" (Mills, 2010a). These new members of the Defense Acquisition Workforce are generally very talented, but recognize that their lack of experience is a challenge that must be overcome. The OSD study and the DAU industry survey reveal that deliberate, proactive engagement between more seasoned government acquisition professionals and their younger, less experienced colleagues would improve overall partnerships shared by the government and industry.

Solutions and Recommendations

An effective DoD–defense industry partnership is not only attainable, but will improve overall acquisition outcomes. The Figure represents a proposed model for the creation of effective partnerships between government program offices and private defense firms. Collective experience and observation demonstrate that the primary desire and expectation of industry firms from government program offices is *flexibility*. In other words, government PMs look for private industry to provide required capability as close to the original schedule and cost estimates as possible, regardless of unforeseen events and changes. Private firms seek *stability* from their government partners. In other words, private industry seeks a measure of confidence with regard to the level of current and future work they will be employed to perform for the government. Stability enables industry to manage subcontract relationships, adjust personnel staffing levels, and forecast company performance for the benefit of their investors.

FIGURE. EFFECTIVE PARTNERSHIP BETWEEN GOVERNMENT AND INDUSTRY



Complete flexibility for the government and complete stability for industry are not attainable. Each entity must help achieve the other's requirements for the partnership to be effective. We suggest that the previously discussed five components for an effective partnership serve as the center of mass through which government and industry should seek to interface.

DAU Support

Within DAU, government and industry PMs have at their disposal an extensive program management and acquisition management tool. While the primary focus of DAU training assets is to enable success in managing DoD acquisition programs, we believe the university could also provide direct support in the effort to establish and sustain effective partnerships.

High-quality acquisition training is available in all of the functional areas that support DoD materiel acquisition programs. DAU's resources extend well beyond the classroom and include a significant online presence. A quick review of the DAU website (http://www.dau.mil) and its related learning resources reveals a large number of educational opportunities targeted to both government and industry employees. The *Defense Acquisition Guidebook* (*DAG*) is a great example of a valuable resource available to industry and government acquisition personnel at any time. The DAG (https://dag.dau.mil/Pages/Default.aspx) provides a graphical and user-friendly portal of DoD acquisition best business practices, acquisition policy, and lessons learned. Another excellent source of acquisition training for both DoD and industry personnel is DAUs Continuous Learning website (http://www.dau.mil/clc/default.aspx), which hosts over 175 Continuous Learning Modules covering critical topics that support all of the 12 Acquisition Workforce functional areas. These learning assets are also available to both DoD and industry personnel 24 hours a day.

Project Management Institute Support

The Project Management Institute (PMI) also offers training and certification opportunities to government and industry personnel. Like DAU-sponsored training, we believe this training would be very effective in the creation and management of partnerships between the two enterprises. This is particularly true since PMI's suite of globally recognized processes will significantly affect the worldwide defense industry in the future.

The field of program management in private industry is guided by both doctrine and best practices. PMI's *Project Management Body of Knowledge* (*PMBOK*®), as embodied in the *PMBOK® Guide*, serves as the repository for both industry-developed doctrine and best practices in program management (PMI, 2008). The PMBOK is the industry standard for program management doctrine and best practices. It represents the PM approach embraced by our industry partners. PMI plays a key role by serving as the granting authority for several American National Standards Institute-based credentials. These include:

- Certified Associate in Project Management (CAPM®)—for integrated product team leaders and members
- Project Management Professional (PMP®)—for project/program managers
- Program Management Professional (PgMP®)—for program/portfolio managers
- Risk Management Professional (PMI-RMP®)—for risk managers
- Scheduling Professional (PMI-SP®)—for scheduling managers

Significant commonality exists between the PMBOK® and government acquisition management doctrine. Like Lewis and Clark, each body of knowledge complements the other. This commonality provides an opportunity for government acquisition professionals to bridge the knowledge gap through the study and accreditation of PMI-sponsored, PMBOK®-based credentials. Government PMs who obtain PMI credentials gain a better understanding/perspective of industry program management processes and best practices.

The process of promoting industry standard credentials as a career progression option for Defense Acquisition Workforce employees would accomplish multiple objectives. First, it would help create a better channel of communication between government and industry personnel by creating a *common understanding*. By focusing on and understanding the industry standard for project management, a common context for project management discussions would exist. The use of earned value management provides a good example of a common process or understanding. Second, PMI's Aerospace and Defense Specific Interest Group (A&D SIG) could supplement, to some degree, DAU's workforce training at large, given the capacity limitations discussed earlier. Lastly, promoting the value of industry standards for project management would demonstrate a commitment from an organization's leadership to the professional development of the individual. The most important resource required for attaining success in government acquisition programs is a well-trained and well-led workforce, composed of both government and industry employees.

Recommended Areas for Consideration

Along with the contributions to effective partnership available through DAU and PMI training, we recommend consideration of the following measures:

Recommendation No. 1—Training With Industry (TWI)

Currently, limited TWI opportunities are afforded DoD acquisition personnel. The OSD study found that "adopt[ing] the training with industry program more widely...[would] be important in improving management of acquisition programs" (DAU, 2009, Comment E61C). We agree with this assessment and recommend that OSD and the defense industry PM offices collaborate to increase the number of TWI offerings made available each year to acquisition professionals.

Recommendation No. 2—Incentivize DAU Course Attendance

In an effort to increase opportunities and funding for contractor attendance at DAU courses, we recommend that government program offices request industry partners, in their contract proposals to the government, provide the names and cost estimates for a finite number of their personnel to complete DAU training. Specifically, these would be industry personnel working in support of the government contract. This arrangement would allow the contractor firm to directly charge for the training of their personnel, thus eliminating the concern of overextending vital overhead funds. In return, the government project office would be supported by personnel equipped with better knowledge of the DoD materiel acquisition processes. Government project offices could secure the necessary funding via the annual DoD planning, programming, budgeting, and execution process.

Recommendation No. 3—Update DAU Course Content

Providing DAU students with a better appreciation for the realities of private defense industry funding challenges would greatly assist with efforts to facilitate effective partnerships among government and industry. The DAU-South Region has already developed a new section for its Intermediate Systems Acquisition (ACQ 201B) course curriculum, in which students are presented the basic instruction on direct, indirect, and loaded rate personnel charges. This is a line of teaching that can and should be incorporated into other DAU courses in all functional areas.

Recommendation No. 4—Develop New Industry-Specific Course Content

DAU recently developed a new course titled, "Understanding Industry." This course was successfully piloted with the Senior Service College Fellowship students at the DAU South Region campus in September 2010. The focus of this new DAU offering is to provide the Defense Acquisition Workforce significant insight into how our industry partners function and support DoD materiel acquisition programs. This course is a comprehensive 2.5 day offering that educates students on the key aspects of our industry partner's business processes and challenges them with a Capstone exercise as well. Overall results of the initial pilot offering were very favorable. Additional course refinement continues.

Recommendation No. 5—Increased DAU Engagement of Industry

In addition, DAU could provide regular engagement opportunities with the employees and leadership of private defense industry organizations to help them better understand the DoDI 5000.02 and associated processes (DoD, 2008). DAU already provides annual seminars to the National Defense Industry Association and its member organizations. Regular affiliations of this sort between DAU and industry would be of significant value to the overall effort to establish and maintain effective government–defense industry partnerships.

Conclusions

Like Lewis and Clark, the government and defense industry need to foster a true and sustained partnership. Other leaders in the DoD acquisition management community agree. Marine Colonel Michael Micucci, project manager for Light Armored Vehicles, noted in the *Marine Corps Systems Command News* (Johnson-Miles, 2009):

> Cost, schedule, and performance requirements are definitely important, and meeting them is key to program success; however, they really represent the lowest common denominator in the professional partnership formed by the defense acquisition professionals and industry…with this in mind, we should explore establishing expectations for industry as a full partner in every success. (p. 1)

Dr. Carter also emphasized the importance of the government–defense industry relationship. “I am not a believer that the defense industry is the enemy; they are our partners. We can’t arm and defend the country without private industry” (Mills, 2010b). Concerted efforts by both government and industry to engage the five facets identified in this discourse will improve both the flexibility industry can provide to the government and the stability government can provide to industry. This “win-win” arrangement will certainly be beneficial for government operations and for industry bottom lines. Even more important than these benefits, effective partnerships between government and industry will provide U.S. and allied warfighters with better capabilities delivered in a more timely and cost-effective manner.

Author Biographies

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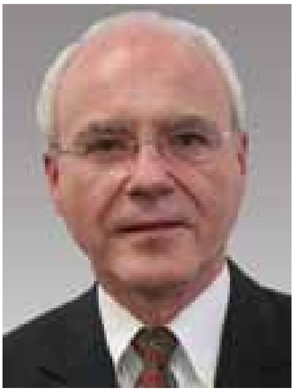

Mr. Allen Green currently works for SAIC, Inc., supporting several DoD efforts. Mr. Green is both an engineer and program manager. He holds Project Management Professional (PMP) and Program Management Professional (PgMP) credentials from the Project Management Institute (PMI). Mr. Green also serves as the president, PMI–North Alabama Chapter, in Huntsville.

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DoD
Industry

LATIST: A PERFORMANCE SUPPORT TOOL FOR INTEGRATING TECHNOLOGIES INTO DEFENSE ACQUISITION UNIVERSITY LEARNING ASSETS

Nada Dabbagh, Kevin Clark, Susan Dass, Salim Al Waaili, Sally Byrd, Susan Conrad, Ryan Curran, Shantell Hampton, George Koduah, Debra Moore, and Capt James Turner, USMC

The Defense Acquisition Workforce is getting younger, and its educational expectations include using advanced and innovative learning technologies. The Defense Acquisition University (DAU) has fully embraced this generational trend and has partnered with several institutions to conduct research on Advanced Learning Technologies, or ALT. One such partnership is with George Mason University's Instructional Technology Immersion Program. The partnership's goal was to examine DAU's current learning assets and identify processes and methods for utilizing innovative learning technology designs. This article summarizes this effort and describes the resulting online performance support tool called LATIST (Learning Asset Technology Integration Support Tool) developed to facilitate the understanding, selection, and integration of ALT by DAU faculty and staff.

Keywords: *Technology, Performance Support, Learning Assets, Education, Training, Learning Asset Technology Integration Support Tool (LATIST)*

image designed by Nina Costine »


LATIST
LEARNING ASSET TECHNOLOGY INTEGRATION SUPPORT TOOL

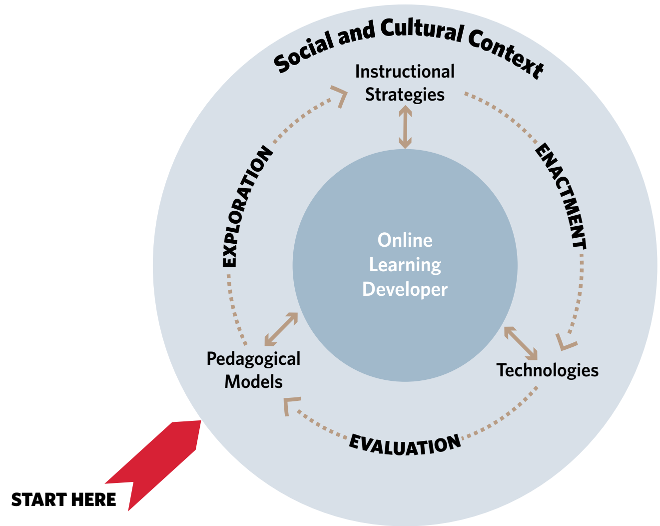
As of September 30, 2008, the Defense Acquisition Workforce was just under 126,000 personnel; an estimated 76 percent of that 2008 workforce was classified as baby boomers—the majority of which are now approaching retirement (DoD, 2007). Waiting in the wings is the gamer generation. As these gamers enter the workforce and subsequently become students at the Defense Acquisition University (DAU), they do so with expectations about their educational environment. The new generation finds classroom settings that have little visual stimulation, passive lectures, and ineffective or unengaging use of integrated technology (Kapp, 2007). DAU recognizes this change in expectations and wants to enhance its learning assets and prepare for the future by smartly integrating available technologies (Anderson, Hardy, & Leeson, 2008). For example, DAU is already using innovative approaches to develop games and simulations designed to improve performance outcomes (Sanchez, 2009). However, the pace from invention to production to maturity of these new technologies is shortening dramatically (Oehlert, 2009).

Keeping pace with these new technologies, their capabilities, and impact as possible tools for training and education is an ongoing challenge. As such, DAU partnered with the Instructional Technology Immersion Program at George Mason University (GMU) to conduct comprehensive research on Advanced Learning Technologies (ALT) in order to determine how best to integrate such technologies into its learning assets. Specifically, the purpose of this research was to:

> Examine current DAU training programs and learning products and identify processes and methods for utilizing innovative learning technology designs and delivery tools within the current DAU learning modalities in order to improve the effectiveness and efficiency of current offerings.

This article summarizes this effort including a description of the instructional design model used to guide this research; the three-step performance analysis process conducted to explicitly define DAU technology integration needs; and the performance support tool, LATIST (Learning Asset Technology Integration and Support Tool), developed to facilitate the understanding, selection, and integration of ALT by DAU faculty and staff.

FIGURE 1. INTEGRATIVE LEARNING DESIGN FRAMEWORK



Research-Driven Design Model

The overarching methodology used to guide this research effort relied on a research-driven approach known as the Integrative Learning Design Framework (ILDF) for E-Learning (Dabbagh & Bannan-Ritland, 2005). The ILDF for e-Learning is an instructional design model that provides a systematic framework for the development of learning assets and products based on sound pedagogy, iterative evaluation, and the socio-cultural context of the learning organization (Figure 1).

The ILDF is a comprehensive and flexible model that draws heavily from the iterative nature of traditional systematic processes of instructional design and can be applied in multiple settings. Specifically, the ILDF consists of three phases:

- Exploration—Investigating and documenting relevant information related to the instructional or training setting, including stakeholders' individual and collective beliefs on learning and solicited information from all involved in the instructional or training situation.
- Enactment—Mapping information gathered in the exploration phase about learning processes, content, and context to existing pedagogical models, considering the characteristics of the selected model(s) to identify and implement effective instructional strategies using technology.
- Evaluation—Determining the purpose, desired results, and methods of evaluation of an online- or technology-

supported learning design, incorporating formative evaluation and revision cycles that result in effective implementation and informative results.

In this research effort, the first phase of the ILDF—Exploration—consisted of conducting a Performance Analysis (PA). Through formal and informal data-gathering techniques and in collaboration with DAU stakeholders, the GMU Immersion team implemented a three-step PA process to (a) identify relevant roles, responsibilities, and processes, (b) define factors for successful performance, and (c) propose possible solutions for effective instructional design. The three-step PA process for this project is explained in the next section.

Performance Analysis Process

The three-step PA process began with a front-end analysis, followed by an extant data analysis, and concluded with a needs assessment.

Front-End Analysis

The front-end analysis provided a preliminary understanding of DAU's education and training program. The analysis relied on informal data-gathering techniques by examining relevant documents such as: the *DAU Course Catalog;* the *Defense Acquisition Review Journal* (now the *Defense Acquisition Research Journal*); the *Defense AT&L* magazine; the *AT&L Human Capital Strategic Plan*; and DAU Directive 709, which addresses the Learning Asset Management Program. Additionally, key stakeholder meetings explored DAU's learning asset development processes, roles, and responsibilities. The analysis indicated DAU's educational philosophy is exemplified through its Performance Learning Model (PLM) (DAU, 2010, p. 28).

The three pillars of the PLM (Career Development, Job Performance, Executive & Leadership) represent the three main types of training and development that the Defense Acquisition Workforce receives (DAU, 2010, p. 28). Training courses, continuous learning modules, performance support, and knowledge sharing capabilities are the primary methods utilized to build DAU's learning environment (DAU, 2008a). These are all considered to be learning assets. Formal courses can be delivered on-site, online, or in a hybrid approach. Informal support is provided through a variety of tools.

For example, DAU provides an extensive Community of Practice (CoP) to help "extend the reach of Subject Matter Experts (SMEs) supporting the workforce" (Garcia & Dorohovich, 2005, p. 21). DAU also supports a virtual library, an electronic *Defense Acquisition Guidebook*, an Ask a Professor service as well as its own version of Wikipedia called Acquipedia.

The front-end analysis also revealed that similar to other learning organizations, DAU faces several challenges and constraints and has multiple motivational drivers when it comes to integrating technology into its learning assets. Challenges included promoting new technologies that may exceed available bandwidth or compromise security standards for some units; constraints included working within an existing learning management system and well-defined certification classes; and drivers included supportive leadership, access to cutting-edge technology, and commitment to advanced technology research. Armed with this preliminary knowledge, an extant data analysis was performed to continue the PA process.

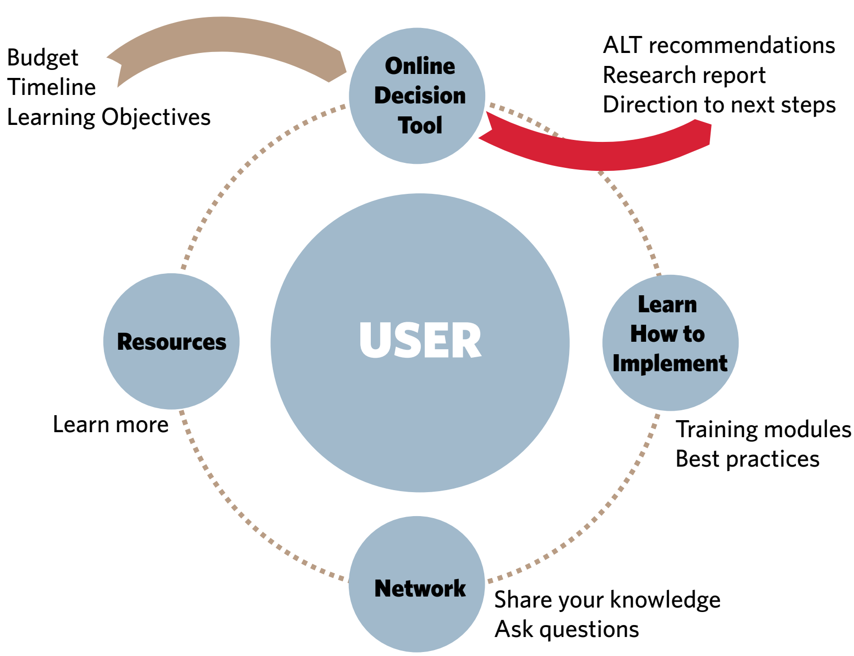
Extant Data Analysis

The extant data analysis revealed that as the provider of acquisition training for the DoD community, DAU supports many external stakeholders and customers including the Services and other Defense Agencies. Within DAU, the Global Learning Technology Center (GLTC) is leading the research on ALT for DAU. The DAU Learning Capabilities and Integration Center (LCIC) is responsible for the development and management of training requirements and content, which traverses 11 functional areas. To support these multiple roles and responsibilities, DAU uses an Integrated Product Team (IPT) approach to develop its learning assets (DAU, 2008b). Commonly, a learning asset IPT is composed of SMEs, a gaming/simulation/technology representative, an instructional systems designer, and a Performance Learning Director (PLD). Depending on the type of learning asset, the use of these roles may vary. In the case of a training course, the SME develops the content document; the instructional systems designer provides recommendations related to learning outcomes and helps define terminal and enabling objectives; the gaming/simulation/technology representative makes recommendations on the use of such technologies in the learning asset; while the PLD oversees and participates, as appropriate. Additionally, functional area representatives have the opportunity to participate and evaluate pilot courses. Once a course is launched, a manager is assigned to oversee postproduction activities such as addressing postcourse surveys that capture student opinions as well as addressing the ever-changing, sporadic requirements that affect content currency, relevancy, and accuracy.

At any point in the learning asset development life cycle process, the recommendation to use learning technologies can be made. However, several factors need to be taken into consideration such as recognizing that duplicate learning assets exist deliberately to accommodate bandwidth constraints. Another factor is speed-to-market, which involves balancing the subject matter vetting process against timeliness of content release. Such factors greatly impact implementing technology recommendations.

The extant data analysis also revealed that DAU needed a formal vehicle or process to effectively diffuse GLTC research findings on how to select and integrate pedagogically appropriate ALT into the life cycle of a learning asset. Furthermore, the analysis revealed that DAU faculty and staff could benefit from an area or "sand-box" to practice and become familiar with ALT. Based on these findings, a potential strategy—namely a conceptual framework comprised of four components—was developed to address these needs (Figure 2). Next, a needs assessment—the third step in the

FIGURE 2. CONCEPTUAL FRAMEWORK



PA process—was conducted to validate these findings and refine the framework.

Needs Assessment

The needs assessment required more formal data-gathering techniques. As such, structured interviews and an online survey were conducted to further the current understanding of roles, decisions, and processes associated with the integration of ALT into DAU's learning assets. The structured interviews consisted of nine sequential questions posed to each of 12 DAU participants, including LCIC leadership, a knowledge project officer, a center director, and eight representatives from the DAU Capital and Northeast Region. The goal of the interviews was to provide qualitative data about the different roles that DAU personnel assume in the process of selecting and integrating ALT into DAU's learning assets as well as identifying factors that influence ALT selection and adoption. At the end of each interview, the conceptual framework (Figure 2) was presented to gather feedback on its usefulness as a vehicle or tool to facilitate technology integration. The online survey was informed by the results of the structured interviews and accessed a wider audience to collect a larger data set. The survey consisted of six forced choice answers targeting demographic data, four Likert-scale questions that targeted respondents' familiarity with ALT, and one Likert-scale question addressing the likelihood that a respondent would use an online framework, namely the conceptual framework.

The interview data resulted in 591 comments, which were aggregated across questions and analyzed qualitatively. Descriptive analysis was conducted on the survey, which consisted of 34 responses. The interview data confirmed that LCIC and GLTC personnel consider and provide recommendations regarding ALT integration at various points in the learning asset development process, and that there is significant interest in incorporating ALT in a pedagogically appropriate manner that would lead to improved learning outcomes. Additionally, 20 factors influencing the selection and integration of ALT were culled from the interviews. These factors were provided in the online survey for rank ordering. The results of the survey revealed that the top five factors were long-term revision feasibility, content stability, bandwidth, ability to replicate across regions, and development cost. Survey respondents also indicated that decisions regarding ALT integration are made across all roles and job titles within GLTC and LCIC, reflective of the IPT approach.

With respect to the conceptual framework, half the interviewees expressed interest in it as both a decision tool that guides ALT selection, and training support on how and why to use different technologies; 83 percent of the survey respondents indicated they would use it. These findings further validated interviewee suggestions that developing a systematic process for technology integration would improve the effectiveness and efficiency of learning asset development. With the completion of the needs assessment, and hence the PA, the GMU Immersion team proceeded to the enactment and evaluation phases of the ILDF to formalize the design and development of the proposed conceptual frameworks as a vehicle for disseminating the latest research on ALT and facilitating the integration of ALT into DAU's learning asset development processes.

Prototype Development

In collaboration with DAU stakeholders, the conceptual framework was named the Learning Asset Technology Integration Support Tool (LATIST). LATIST would be developed as an area where users could explore the latest research on ALT; as a decision tool that would guide the selection of ALT based on users' instructional needs and contextual factors; and as an application area where users could practice implementing ALT. Although the initial vision for the conceptual framework included a user community for information sharing and collaboration, this was not pursued for development since DAU has an extensive CoP infrastructure. The specifics of the content and functionality of the three components of LATIST would be determined through a usage-centered design process described in the next section.

Usage-Centered Design Process

A usage-centered design process is commonly used in software development and focuses on identifying user needs to develop a product that allows users to fulfill their needs in an easy, effective, and efficient way (Constantine & Lockwood, 1999). Through content and task analysis, user needs were confirmed, tasks necessary for users to obtain optimal benefit while using LATIST were identified, and content requirements were established based on projected user scenarios and use cases. As a result, it was determined that LATIST would consist of three components that would allow the user to:

1. Explore what the research says about a technology such as advantages and disadvantages;
2. Select a best technology for user conditions such as learning objectives and bandwidth constraint; and
3. Review and learn how to apply a selected technology.

Additionally, the results of the content and task analysis revealed that LATIST would best be utilized as an electronic performance support system (EPSS). An EPSS is an easily accessible, integrated electronic environment that provides immediate, individualized support so employees can perform their duties with minimal intervention by others (Dickelman, 2004). A performance support SME recommended that for maximum effectiveness, information in LATIST should be explicit, accessible, and usable; and confirmed that the three components of LATIST represented a successful integration of process and knowledge.

Design Requirements

LATIST was to support information access in an anytime, anyplace environment, including mobile. Therefore, LATIST was to be browser-based, quickly accessible from the Internet. The design requirements were derived specifically from use cases that delineated the features and functionality of the EPSS based on user perspectives. These included the capability for users to print, save, search, and share content; create a personal space of notes and personally rated content; upload content; navigate across components based on a selected technology; and access support features such as Help and Dictionary. Given the dynamic nature of the "select best technology" component and the need for searchable research resources, a back-end database was necessary to manage the content. Hence, a Content Management System (CMS) was used to build LATIST. Based on these requirements and discussions with DAU stakeholders and information technology specialists, the CMS WordPress was selected to build the core framework for LATIST. WordPress is an open-source blog publishing CMS application powered by an open-source server-side scripting language known as Hypertext Preprocessor (PHP) and by MySQL—a relational database management system that can also be used for content management. LATIST navigation was designed to be intuitive and to address these four focal use cases:

- A user who is not familiar with what technology can do in a teaching and learning context and wants to review what the research says about technology;
- A user who has a known learning outcome (instructional objective) and/or contextual factors and wants to see what technologies might be beneficial for that instance;
- A user who wants to learn how to apply a technology and practice those steps; and

- A user who has been directed to use a particular technology and wants to learn what the research says about the technology and how to apply it.

These design requirements were documented using flowcharts and wireframes to convey the navigation and site architecture for an external software vendor to develop the LATIST prototype. Additionally, two logical data models were developed to support the dynamic nature of the "select best technology" component of LATIST and enable a searchable repository of the research. Furthermore, two short videos were designed and developed by a video producer to introduce users to the purpose, capabilities, and navigation of LATIST. Based on the documented requirements, an initial prototype was developed to begin usability testing.

Usability Testing

Two rounds of usability testing were conducted to iteratively improve the prototype based on expert and user feedback. Both rounds were intended to determine design inconsistencies and usability problems to establish user performance and user satisfaction levels. Both rounds consisted of two phases; Phase I relied on the GMU Immersion team and proxy participant feedback while Phase II relied on end-user (DAU) participant feedback.

In Round 1, the usability testing focused on participant perceptions and sought their recommendations for improvement. In Phase I, three GMU faculty members provided expert ISD (Instructional System Design) review. In Phase II, DAU stakeholder-users conducted an asynchronous review of the prototype and answered a brief online survey. Survey results were generally positive regarding the layout, navigation, and overall functionality of the LATIST prototype. Improvements were accomplished in preparation for Round 2 usability testing. In Round 2, Phase I testing again relied on GMU faculty members to provide expert ISD review. In Phase II, testing took place at DAU's Fort Belvoir campus to capture representative user performance and user satisfaction under controlled testing conditions. Nine participants selected by DAU received a brief overview of LATIST prior to the usability testing. Once the test began, participants evaluated LATIST using a Web browser organic to the DAU computer. A GMU Immersion team member observing the test guided the participants to the LATIST website. Participants were encouraged to think-aloud as they used LATIST while completing scenarios provided for the test. Their thoughts were captured using a tape recorder, and in some cases supplementary notes were taken. Round 2 results indicated that the majority of participants regarded LATIST as an online support tool that would be helpful in raising awareness of technology options among DAU staff and that, with further development, LATIST would be a good resource. One participant noted that LATIST would be a "good idea generator." Recommendations stated independently by at least two of the nine participants included:

- Add more multimedia resources as the current use of videos was good;
- Add more examples explaining how to integrate technology into learning assets;
- Add a means to easily share information in the tool such as through social media or e-mail options;
- Ensure the tool is scalable, the information relevant, and the content up-to-date; and
- Provide more connectivity across components and between subcomponents within "select best technology" component.

LATIST Prototype

Based on the usability testing results, the LATIST prototype was revised to include the main features and functions intended to support DAU faculty and staff in integrating ALT. As such, LATIST is best described through its main navigation pages: LATIST Home Page, Explore Research, Select Best Technology, and Apply Technology.

The LATIST Home Page introduces the purpose and capabilities of LATIST, providing two video links that further explain what LATIST is and how to use it (Figure 3). LATIST provides many global features. Users will be able to quickly access the three main components: Explore Research, Select Best Technology, and Apply Technology as well as access any one page of content using a Technology quick links function. In the future, the team envisions that users will be able to log in to add personal features such as rating articles, uploading content, and taking personal notes. An advanced search function would be programmed to locate all resources based on filtering agents such as date, title, keyword, and author. A dictionary would be included to provide quick reference on what a technology is and define the influential factors significant to the selection of ALT. A "Help" feature would target technical issues related to system features such as uploading documents to LATIST.

The Explore Research component of LATIST is a research-based body of knowledge on ALT organized into three broad categories: (a) Social Media, (b) Virtual Worlds/Games and Simulations, and (c) Mobile Technologies (Figure 4). While one user may be satisfied with reviewing a technology overview, advantages/disadvantages,

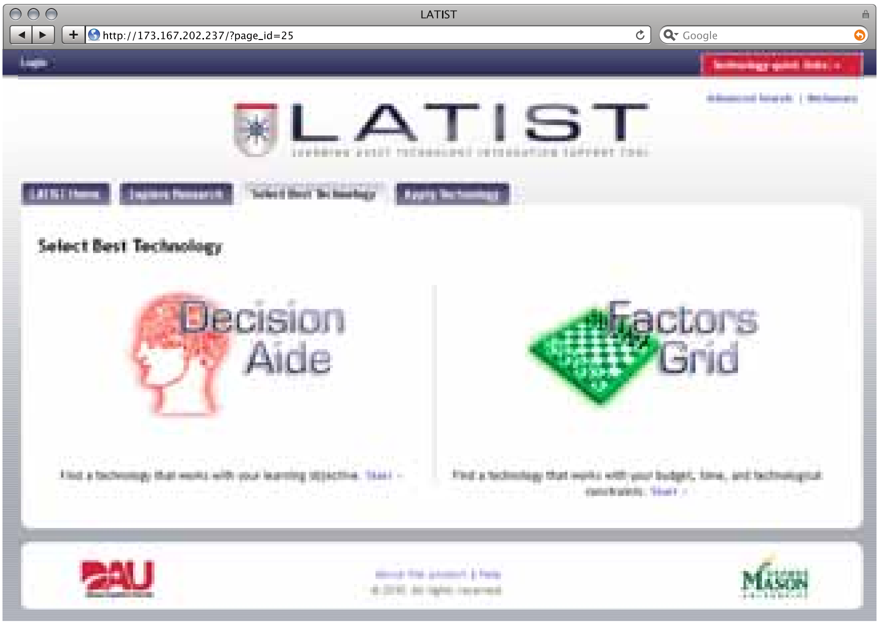
FIGURE 3. LATIST HOME PAGE

and best practices of a specific ALT, another may want to pursue more in-depth research by reviewing the available literature of that technology. The team envisions that DAU faculty and staff will be able to print, share, add, upload, mark their favorites, rate resources, and select articles rated highly by their peers. Additionally, in the future the system will provide "Amazon-type" recommendations for other resources to review based on tagging or other such classification-type metadata. Users will be able to easily and intuitively move within the different information sections of the Explore Research component and across all LATIST components.

The Select Best Technology component of LATIST guides users to make informed decisions about which technologies to integrate into learning assets in a pedagogically sound manner while taking DAU-specific criteria into consideration. This component has two subcomponents: the Decision Aide and the Factors Grid (Figure 5). Through the Decision Aide, users select a learning objective level that matches the learning objective for an identified DAU course or learning asset. The Decision Aide responds by providing a list of potential instructional strategies for that learning objective level.

FIGURE 4. EXPLORER RESEARCH: BLOGGING—OVERVIEW

FIGURE 5. SELECT BEST TECHNOLOGY HOME PAGE

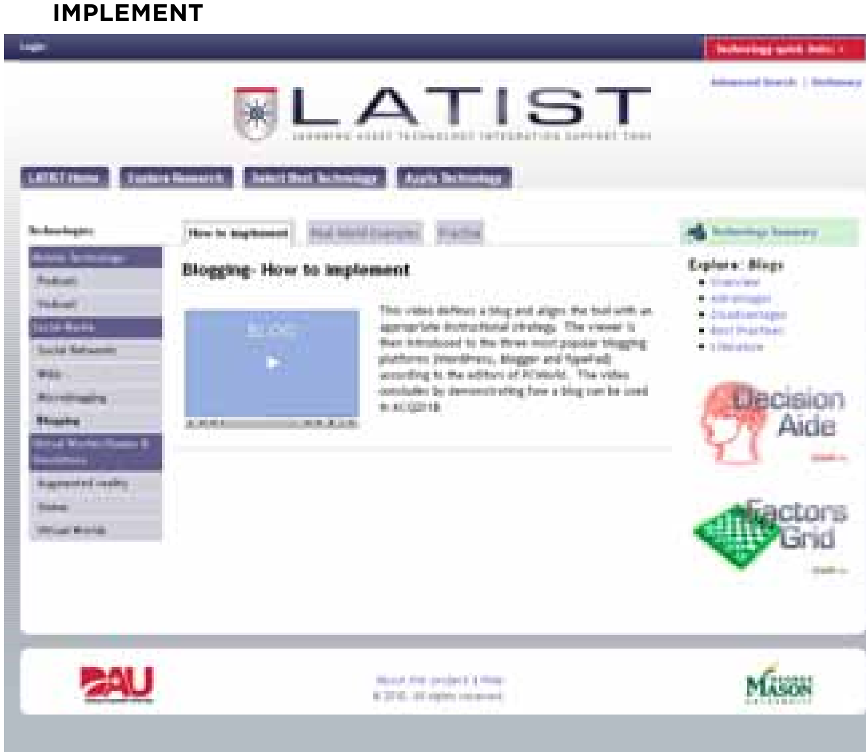


Based on the user-selected instructional strategy, the system returns a "best technology." The Factors Grid allows the user to evaluate technologies based upon criteria specific to DAU such as bandwidth, information stability, development cost, maintenance cost, and speed-to-market. The team envisions that these two tools would become connected or intertwined so both types of considerations (learning objectives and influential factors) can be addressed in a singular activity.

The Apply Technology component enables the user to learn how to apply a specific technology by providing options to learn how to implement it; view real world examples of use in a DAU context and other business, military, and educational contexts; and gain hands-on practice (Figure 6). The user can access the information through a combination of embedded or hyperlinked videos, text documents, or URLs to external websites. The information provided in the Apply Technology component will allow the user to incorporate a selected technology suitable for a learning asset.

The LATIST Home Page introduces LATIST to new and occasional users while the three components of LATIST work hand-

FIGURE 6. APPLY TECHNOLOGY: BLOGGING—HOW TO IMPLEMENT



in-hand to facilitate the understanding, selection, and integration of ALT by DAU faculty and staff into DAU's learning assets.

Conclusions

DAU is committed to research and excellence in education and training. As such, a partnership between DAU and GMU's Instructional Technology Immersion Program was formed to conduct research on ALT. A performance analysis revealed that DAU faculty and staff could benefit from a tool that summarizes research on ALT, guides selection of ALT, and enables implementation of ALT. As a result, LATIST was designed as a scalable electronic performance support tool that allows DAU faculty and staff to: (a) explore what the research says about a technology such as advantages/disadvantages; (b) select a best technology for user conditions such as learning objectives and bandwidth constraints; and (c) review and learn how to apply a selected technology. A usage-centered design approach was used to develop the LATIST prototype, and two rounds of usability testing were conducted to iteratively improve its design and functionality. The results revealed that overall, LATIST was perceived by DAU stakeholders and participants as a highly valued performance support system. Specifically, LATIST was perceived as: (a) useful in raising awareness of technology options among DAU faculty and staff, (b) a "good idea generator," and (c) a "good resource." Additionally, participants recommended enhancements to increase performance and user satisfaction. Implementing these recommendations and fully realizing the envisioned functionality associated within each LATIST component will ensure that DAU faculty and staff can use LATIST to make research-driven and pedagogically sound decisions regarding the integration of ALT into their learning assets to improve their effectiveness and efficiency, and empower the Defense Acquisition Workforce to better manage and execute job performance. So how will you choose a technology for integration into a learning asset? Check out LATIST at http://cehd.gmu.edu/LATIST.

Authors' Note

LATIST was designed and developed in academic year 2009–2010 at George Mason University (GMU) by a team of nine graduate students enrolled in GMU's Instructional Technology (IT) Immersion Program and supervised by IT faculty Dr. Nada Dabbagh and Dr. Kevin Clark. The Immersion Program, a resident graduate program of the College of Education of Human Development, is designed to allow teams of 6–10 graduate students to immerse themselves in project-based learning experiences that require them to utilize and apply Instructional Design and Development (IDD) principles and processes through authentic practice. This goal is achieved through research and training development grants that engage student teams and faculty in real-world IDD projects. These grants enable the integration of research, theory, and practice in an authentic problem-solving context, resulting in a beneficial situation for the funding organization, the university, the program, the students, and the faculty. For more information about the immersion program philosophy and projects, visit http://immersion.gmu.edu/. To learn more about this DAU research project, visit http://immersion09.onmason.com/.

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The Defense Acquisition 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 *Defense ARJ* website.

We encourage *Defense 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

Book Reviewed:
Megaprojects and Risk: An Anatomy of Ambition

Author(s):
Bent Flyvbjerg, Nils. Bruzelius, and Werner Rothengatter

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Cambridge, Cambridge University Press

Copyright Date:
2003

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Softcover: 207 pages

Reviewed by:
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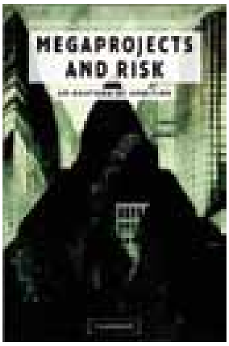

Review:

Megaprojects have some distinct characteristics: Unusually large by definition, they require significant amounts of capital expenditure (hundreds of millions of dollars) and human resources; they produce complex systems with high levels of technological innovation; and they have the potential to change their surrounding economic, social, and organizational environment.

It is through projects and programs that assets and knowledge are developed, and those assets and infrastructure enable the necessary operations and supply chains. Clearly, they are important for the organizations, individuals, economy, and society. However, it is also clear that the performance record of megaprojects is quite poor, with significant cost and schedule overruns.

The authors look at the performance record of megaprojects from around the globe though a risk "lens." They provide an in-depth analysis of three transport megaprojects: the Channel Tunnel between the United Kingdom and France; the Great Belt bridge/tunnel in Denmark; and the Øresund Bridge between Denmark and Sweden. They focus on the front-end part of the projects, that is, the feasibility/appraisal stage. These detailed analyses are complemented with data from other major projects in both the public and private sectors, including the transport, information technology, oil and gas, and aerospace sectors.

Through their analyses, the authors critique the "conventional approach to megaproject development" (p. 86) and come up with a number of interesting findings. For example, "cost estimates used…in decision making…are systematically and significantly deceptive" (p. 20); "over optimistic estimates of project viability in the initial planning stage and inadequate analysis of risk and uncertainty" (p. 41); and "accountability is low for parties involved in project development and implementation" (p. 45).

The main reasons for poor performance identified by the authors include the poor consideration of risks; institutional issues (such as lack of stakeholder involvement or a lack of clearly defined roles); and a lack of accountability in the project decision-making process. The authors call, perhaps optimistically, for a mechanism that will enforce accountability and transparency. To this end, they provide an overview of a number of instruments that might help.

This book is of interest to the defense acquisition community, in part because it shows that overruns are not limited to defense projects alone, but also because it argues that the cause of cost growth is not due solely to "unrealistically optimistic estimates," as Schwartz (2010, p. 16) cites in a recent report for Congress. Rather, there are other dynamics at play here that contribute to project escalation: organizational, cultural, behavioral, and cognitive. It is through understanding these dynamics that the problems surrounding project escalation can begin to be addressed more effectively.

REFERENCE

Schwartz, M. (2010). *The Nunn-McCurdy Act: Background, analysis, and issues for Congress.* CRS Report for Congress (Report No. 7-5700). Washington, DC: Congressional Research Service.

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