NPS-AM-17-014

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Perspectives from a Retired Teacher of Defense Acquisition

16 November 2016

Michael W. Boudreau, Senior Lecturer

Graduate School of Business & Public Policy

Naval Postgraduate School

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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Introduction

Recently, I retired from government service after 28 years of military service and 20 years of teaching at the Naval Postgraduate School. I've been very fortunate to have seen acquisition from the perspective of a military user, a maintainer of Army equipment, a builder of M1 Abrams Tanks, a staff officer in the Pentagon, and a project manager (PM). This is my opportunity to provide my perspective on the current state of defense acquisition.

It comes as no surprise to those involved in the development of warfighting equipment that defense acquisition is multi-faceted, requiring intensive management and involving three systems: the Joint Capabilities Identification and Development System (JCIDS), which establishes requirements; the Planning, Programming, Budget and Execution (PPBE) System, which provides the funding; and the Defense Acquisition System (DAS), which executes the acquisition. Unfortunately, these three systems do not interoperate seamlessly. As if this is not enough of a challenge, frequently the Office of the Secretary of Defense (OSD) and Congress "change the rules" by which acquisition must be accomplished (Dillard, 2003). When we collectively ask ourselves about the state of defense acquisition, most would acknowledge that there is a longstanding and ongoing trend of acquisition programs failing to achieve acquisition program baseline (APB) goals. This has been thoroughly documented by Government Accountability Office (GAO)—formerly the General Accounting Office—reports.

Given that defense acquisition is and will remain multi-faceted, imperfect, and evolving, must its future be completely and irremediably bleak? I suppose the answer to this question depends on whom you ask. Our government watchdog organizations, particularly the GAO, can point to many examples of management mistakes that have been made or are currently being made. If you look at the three metrics of every program—cost, schedule, and performance—many acquisition programs over several decades have missed or will miss achieving Acquisition

Program Baseline goals in one and maybe all three of these metrics (GAO, 2015b, 2016).

Sometimes program managers (PMs) sign up for cost or schedule goals that are unachievable—recently described by the GAO as a systemic problem that they refer to as being “in equilibrium.” The GAO describes being in equilibrium as “competing forces consistently lead to starting programs with slim chances of being on time and within cost” (GAO, 2015c). In many programs, technologies have not been ready to support mature, production-ready systems—leading to schedule concurrency (e.g., redesigning, retesting, and manufacturing—simultaneously), which often brings delays and cost increases, and then further delays. It is easy to paint a dismal picture of defense acquisition.

The Bleak

From my perspective, the "elephant in the room" is the DoD's propensity to launch "mega" programs that are beyond its ability to manage successfully. The DoD's really large programs, such as the Army's Future Combat System (FCS), the multi-service and multi-national Joint Strike Fighter (F-35), and the Navy's USS *Gerald R. Ford* aircraft carrier (CVN 78) each reflect enormous system complexity (multiple variants, multiple new technologies, and large amounts of associated software) that continue to bedevil acquisition managers. These three programs are very different from one another, but each suffers (or suffered—past tense—in the case of the FCS, which was terminated in 2009) from unmanageable complexity. This is no criticism of the management teams that have guided these very important programs. Rather, it's a criticism of leadership decisions to enter into mega-programs that risk our treasure and, due to their complexity, are unlikely to succeed.

The challenges of system complexity include technology immaturity, both hardware and software, which may be most intractable in mega-programs, but also affect programs of all sizes in all the military services. At present, the pathways to improved outcomes for hardware and software appear to lead in different directions. Technology development leading to advanced hardware solutions needs be matured in the technology base before being handed over to emerging warfighting systems. The timing of maturing technology (e.g., a new missile launch method or a new fire control sensor) may not meet the schedule of a warfighting system development; if not, the new technology should be added to warfare systems incrementally (GAO, 2015c, pp. 3, 4), so as not to interrupt the completion schedule of an emerging warfighting system. On the other hand, software must be developed or adapted uniquely for a warfighting system—developed using highly disciplined systems engineering processes. This suggests to me that software development will normally require major up-front effort where about half of the software development cost is expended prior to the program's Milestone B (Naegle & Petross, 2007, p. 27). It also suggests that software may be a pacing activity within hardware/software program developments—a fact that is reflected in many of the developmental programs reported on by the GAO in its March 2015 report, *Defense Acquisitions: Assessments of Selected Weapon Programs* (pp. 51–53, pp. 56–150).

Acknowledging that many acquisition programs have struggled during their development, much work has been accomplished, particularly over the past 20 years, to help PMs to successfully manage their programs. In the next section, I suggest practices that I argue will help PMs and their teams to understand their programs more clearly and manage them more effectively. I offer no statistical data to support my contentions, although some of my references contain statistics.

The Hopeful

Here are four acquisition practices that can make a big difference for those who will apply them conscientiously and with discipline.

Technology Readiness Assessment (TRA) Guidance, May 2011: Technology Readiness Levels (TRLs)

The Technology Readiness Assessment (TRA) Guidance, was most recently published in May 2011. Technology Readiness Levels (TRLs) were developed by the National Aeronautics and Space Administration (NASA) in the 1980s and adapted by the United States Air Force (USAF) Research Laboratory (GAO, 1999a). The GAO encouraged the DoD to adopt TRLs, and in 2001, the DoD did adopt the use of TRLs in major programs ("Technology Readiness," 2011). Currently, TRAs are required by DoDI 5000.02 for major defense acquisition programs (MDAPs) at Developmental Request for Proposal (RFP) release, Milestone B, and Milestone C (Office of the Under Secretary of Defense for Acquisition, Technology, & Logistics [OUSD(AT&L)], 2015, p. 57).

Figure 1 shows the nine TRLs used to describe the developmental progress of emerging systems as they pass through their prescribed milestones and phases.

Nine Technology Readiness Levels (TRLs)

TRL 1: Basic principles observed and reported

TRL 2: Technology concept and/or application formulated

TRL 3: Analytical and experimental critical function and/or characteristic proof of concept

TRL 4: Component and/or breadboard validation in a laboratory environment

TRL 5: Component and/or breadboard validation in a relevant environment

TRL 6: System/subsystem model or prototype demonstrated in a relevant environment

TRL 7: System prototype demonstrated in an operational environment

TRL 8: Actual system completed and qualified through test and demonstration [This is the end of true system development.]

TRL 9: Actual system proven through successful mission operations

Figure 1: Nine Technology Readiness Levels (TRLs). Source: Assistant Secretary of Defense for Research & Engineering TRA Guidance, (2011).

Having a common framework for technology development and common language to describe the waypoints for technology development are enormously useful for acquisition managers. Prior to these standardized TRL descriptions, our understanding of the progress of developmental programs was significantly less clear and crisp; to characterize our progress, we used to rely on terminology that meant different things to different people. Today, the use of the TRLs is much more precise and reduces the likelihood of misunderstanding whether a developing system has successfully progressed to a specific intermediate milestone.

Manufacturing Readiness Levels (MRLs) Deskbook, Ver. 2.2.1, October 2012

The manufacturing readiness levels (MRLs) closely parallel TRLs. Figure 2 displays the 10 MRLs that describe and guide progress in preparation for the manufacture of emerging warfighting systems as programs pass through their prescribed milestones and phases.

Manufacturing Readiness Levels (MRLs)

MRL 1:	Basic manufacturing implications identified
MRL 2:	Manufacturing concepts identified
MRL 3:	Manufacturing proof of concept developed
MRL 4:	Capability to produce the technology in a laboratory environment
MRL 5:	Capability to produce prototype components in a production relevant environment
MRL 6:	Capability to produce a prototype system or subsystem in a production relevant environment
MRL 7:	Capability to produce systems, subsystems, or components in a production representative environment
MRL 8:	Pilot line capability demonstrated; ready to begin Low Rate Initial Production
MRL 9:	Low rate production demonstrated; capability in place to begin Full Rate Production
MRL 10:	Full Rate Production demonstrated and lean production practices in place

Figure 2: Manufacturing Readiness Levels (MRLs). Source: Office of the Secretary of Defense [OSD] Manufacturing Technology Program and Joint Service/Industry Manufacturing Readiness Level [MRL] Working Group, (2012)

These manufacturing readiness metrics overlay the milestones and phases of the Defense Acquisition System (DAS) and provide very concrete measures of manufacturing preparation and activity that culminate in full-rate production. Besides the manufacturing readiness levels, the *MRL Deskbook* also identifies nine manufacturing risk areas that need to be tracked through each of the MRLs. These risk areas, or threads and sub-threads, comprise activities that must be managed to ensure that manufacturing is thoroughly planned and carefully executed and tracked.

The threads and sub-threads are as follows: technology and industrial base; design; cost and funding; materials; process capability and control; quality management; manufacturing workforce to include both engineering and production; facilities; and manufacturing management (Office of the Secretary of Defense [OSD] Manufacturing Technology Program and Joint Service/Industry Manufacturing Readiness Level [MRL] Working Group, 2012, pp. 2.8–2.9).

Knowledge Management

Since 1998, the GAO has emphasized that critical knowledge must be understood at selected decision points before allowing a developmental acquisition program to proceed to the next step. In 1998, the knowledge points had begun to take shape, but were less detailed than they are today. In Figure 3, the three knowledge points (KP) from 1998 are described.

The GAO's 1998 Knowledge Points

Knowledge Point 1—Customer requirements and technological capability are matched: "Employ a disciplined process to match requirements with technological capability before the product development process begins. This process is grounded in production realities that demand **proof that the technology will work and can be produced at an acceptable cost**, on schedule, with high quality."

Knowledge Point 2—The design will perform as required: "Near certainty that … product designs … meet customer requirements … critical design review to review engineering drawings, confirm the design is mature, and freeze it to minimize changes in the future. … [The design is] essentially complete when about 90 percent of the engineering drawings are completed."

Knowledge Point 3—Production units will meet cost, quality, and schedule objectives: "Reaching this point means more than knowing the product [can] be manufactured; it mean[s] that all key processes [are] under control, such that the quality, volume, and cost of their output [are] proven and acceptable."

Figure 3: The GAO's 1998 Knowledge Points. Source: GAO (1998)

In 2015, the GAO published a table of required knowledge, as shown in Figure 4, containing specifics for application of knowledge point management within the DoD (GAO, 2015b, pp. 171–172).

Best Practices for Knowledge-based Acquisitions
Knowledge Point 1: Technologies, time, funding, and other resources match customer needs. Decision to invest in product development
Demonstrate technologies to a high readiness level—Technology Readiness Level 7—to ensure technologies will work in an operational environment [Note: DOD considers Technology Readiness Level 6, demonstrations in a relevant environment, to be appropriate for programs entering system development; therefore GAO has analyzed programs against this measure as well as their preference for demonstration in an operational environment.]
Ensure that requirements for product increment are informed by preliminary design review using systems engineering process (such as prototyping of preliminary design)
Establish cost and schedule estimates for product on the basis of knowledge from preliminary design using systems engineering tools (such as prototyping of preliminary design)
Constrain development phase (5 to 6 years or less) for incremental development
Ensure development phase fully funded (programmed in anticipation of milestone)
Align program manager tenure to complete development phase
Contract strategy that separates system integration and system demonstration activities
Conduct independent cost estimate
Conduct independent program assessment
Conduct major milestone decision review for development start
Knowledge Point 2: Design is stable and performs as expected. Decision to start building and testing production-representative prototypes
Complete system critical design review
Complete 90 percent of engineering design drawing packages
Complete subsystem and system design reviews
Demonstrate with system-level integrated prototype that design meets requirements
Complete the failure modes and effects analysis
Identify key system characteristics
Identify critical manufacturing processes
Establish reliability targets and growth plan on the basis of demonstrated reliability rates of components and subsystems
Conduct independent cost estimate
Conduct independent program assessment
Conduct major milestone decision review to enter system demonstration
Knowledge Point 3: Production meets cost, schedule, and quality targets. Decision to produce first units for customer
Demonstrate manufacturing processes
Build and test production-representative prototypes to demonstrate product in intended environment
Test production-representative prototypes to achieve reliability goal
Collect statistical process control data
Demonstrate that critical processes are capable and in statistical control
Conduct independent cost estimate
Conduct independent program assessment
Conduct major milestone decision review to begin production

Figure 4: Best Practices for Knowledge-Based Acquisitions. Source: *Assessments of Selected Weapon Programs* [GAO-15-342SP] (2015)

I’m convinced that the GAO is right about knowledge point management. The definitions of required knowledge are clear, and the specific review points are easily aligned to Milestone B, the critical design review (CDR) assessment, and Milestone C. Although the terminology of knowledge point management and the GAO’s specific recommendations have not completely carried over into DoDI 5000.02, its companion document, DoD Directive (DoDD) 5000.01, is consistent with the intent of GAO knowledge point management, as shown by the following extract.

> E1.1.14. Knowledge-Based Acquisition.
>
> PMs shall provide knowledge about key aspects of a system at key points in the acquisition process. PMs shall reduce technology risk, demonstrate technologies in a relevant environment, and identify technology alternatives, prior to program initiation. They shall reduce integration risk and demonstrate product design prior to the design readiness review. They shall reduce manufacturing risk and demonstrate producibility prior to full-rate production. (OUSD[AT&L], 2007, p. 7)

The OSD policy guidance is clear, but not as specific as the GAO recommends; in retrospect, acquisition leaders have a track record of too readily ignoring a program’s lack of “program knowledge” and forging ahead optimistically, hoping that missing “knowledge” will somehow show up. Justification for ignoring knowledge points appears misguided with the result that the defense acquisition landscape is littered with programs that did not have sufficient “knowledge” but were authorized to move forward anyway. The outcomes, beyond poor test results, have been program cost growth, schedule delays, warfighting systems that only marginally perform their missions, unexpectedly high maintenance and retrofit costs, unachievable readiness goals, and even systems that have been produced but cannot be deployed because they are unsuitable or ineffective (Director of Operational Test and Evaluation [DOT&E], 2015; GAO, 2015b, pp. 5, 6, 22, 54; GAO, 2015a, p. 197; GAO, 2015c, p. 2; Defense Science Board Task Force on Developmental Test & Evaluation, 2008, pp.1–3).

In my opinion, the realistic expectation within the acquisition community ought to be that typical PMs will keep pushing their programs forward until told to halt by their leadership. Therefore, if a program is not ready to move to the next developmental phase, the milestone decision authority (MDA) has got to be tough and disciplined, not approving advancement of the program to the next acquisition phase until it meets its knowledge requirements to ensure reasonable likelihood of success.

Reliability Growth

Through the efforts of the DOT&E (2015) and the Defense Science Board (2008), the impact of poor reliability of warfighting systems has been clearly linked to the sustainment cost of warfighting systems. As a result of research carried out by the DOT&E and the Defense Science Board, reliability and maintainability have been re-identified as an integral part of the systems engineering process and must be reported in connection with the Systems Engineering Plan (SEP) at Milestone A, the Development RFP Release Decision Point, Milestone B, and Milestone C. For acquisition category I (ACAT I) programs, reliability growth curves showing the growth strategy must be included in the SEP and the test and evaluation master plan (TEMP) and be tracked until reliability thresholds are achieved (OUSD[AT&L], 2015, p. 85).

In summary, the four practices described in this paper (that is, Technology Readiness Assessment, Manufacturing Readiness Assessment, Knowledge Management, and Reliability Growth) all appear to be defense acquisition best practices that put acquisition developmental programs on the right track to achieve improved program outcomes.

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