NPS-AM-14-C11P20R02-071

PROCEEDINGS
OF THE
ELEVENTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM

THURSDAY SESSIONS
VOLUME II

Effectiveness of Competitive Prototyping and Preliminary Design Review Prior to Milestone B

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Published April 30, 2014

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL

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.

Panel 20. Enabling Affordable Programs Through Informed Early Decisions

Thursday, May 15, 2014	
3:30 p.m. – 5:00 p.m.	**Chair: Michael McGrath,** Vice President, Systems & Operations Analysis, Analytic Services Inc. ***AoAs: Toward a More Rigorous Determination of Scope*** George Thompson, Analytic Services Inc. Jaime Frittman, Analytic Services Inc. John Yuhas, Analytic Services Inc. ***Effectiveness of Competitive Prototyping and Preliminary Design Review Prior to Milestone B*** William Fast, Naval Postgraduate School ***Valuation of Capabilities and System Architecture Options to Meet Affordability Requirement*** Ronald Giachetti, Naval Postgraduate School

Effectiveness of Competitive Prototyping and Preliminary Design Review Prior to Milestone B

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Abstract

The 2013 Annual Report on the Performance of the Defense Acquisition System (USD[AT&L], June 28, 2013) identified a need for additional analysis of recent acquisition policies (DoDI 5000.02, December 2008) to reduce program technical risk by requiring competitive prototyping for risk reduction and a Preliminary Design Review (PDR) before Milestone B. This research uses cost and schedule estimates from Major Defense Acquisition Programs (MDAPs) to determine if competitive prototyping and PDRs held prior to Milestone B have resulted in mature technologies (defined as Technology Readiness Level 6 or above) and subsequently reduced program cost and schedule slippage.

Introduction

Research Purpose and Questions

The purpose of this research is to determine if the DoD Instruction 5000.02 policies for Major Defense Acquisition Programs (MDAPs) relating to competitive prototyping, technology readiness, and Preliminary Design Review (PDR) prior to Milestone (MS) B are having the desired effect on program outcomes. To help evaluate these policies, the following research questions are answered:

1. Does the knowledge from competitive prototyping and a PDR conducted prior to MS B result in better decisions relative to requirements, design, and resources?
2. What are the effects of the competitive prototyping, technology readiness, and PDR policies on program costs and program schedules?

Background

On June 28, 2013, the Under Secretary of Defense, Acquisition, Technology, and Logistics (USD[AT&L]) released his Performance of the Defense Acquisition System 2013 Annual Report. In the preface to the report, The Honorable Frank Kendall called for data-driven analysis to find out what was working in the defense acquisition process. The report concludes with several policies and processes for additional analysis, including

- Setting Preliminary Design Review (PDR) before Milestone B
- Competitive Prototyping for Risk Reduction, not Proof of Concept
- Reducing technical risks during Technology Development phase

(USD[AT&L], 2013b, p. 105)

These three policies all relate to technical risk reduction through competitive prototyping to inform requirements trades prior to Milestone B. These policies were first included in the December 8, 2008 version of DoD Instruction 5000.02, *Operation of the Defense Acquisition System.* The next year, several of these policies were codified in the *Weapon System Acquisition Reform Act (WSARA) of 2009* (Public Law 111-23; WSARA of 2009, §§ 201 and 203).

However, the policies actually begin with a memorandum by a former USD(AT&L), the Honorable John Young. On September 19, 2007, Young mandated that the Military Services and Defense Agencies "formulate all pending and future programs with acquisition strategies and funding that provide for two or more competing teams producing prototypes through Milestone (MS) B." Young went on to claim that "competing teams producing prototypes of key system elements will reduce technical risk, validate designs, validate cost estimates, evaluate manufacturing processes, and refine requirements. In total, this approach will also reduce time to fielding" (USD[AT&L], 2007). Young's policy memorandum and related policies on technology readiness and the use of an early PDR were incorporated into the December 8, 2008, version of DoD Instruction 5000.02, *Operation of the Defense Acquisition System*, as follows in Table 1.

Table 1. Policies as Found in DoD Instruction 5000.02, December 8, 2008
(DoD, 2008, pp. 17–21)

Reference	Policy
Competitive Prototyping **Enclosure 2 Para 5c(9)**	The Technology Development Strategy (TDS) and associated funding shall provide for **two or more competing teams** producing **prototypes of the system and/or key system elements** prior to, or through, Milestone B. Prototype systems or appropriate component-level prototyping shall be employed to reduce technical risk, validate designs and cost estimates, evaluate manufacturing processes, and refine requirements. Information technology initiatives shall prototype subsets of overall functionality using one or more teams, with the intention of reducing enterprise architecture risks, prioritizing functionality, and facilitating process redesign.
Preliminary Design Review **Enclosure 2 Para 5d(6)**	When consistent with Technology Development Phase objectives, associated prototyping activity, and the MDA-approved TDS, **the PM shall plan a Preliminary Design Review (PDR) before Milestone B.** PDR planning shall be reflected in the TDS and shall be **conducted for the candidate design(s) to establish the allocated baseline (hardware, software, human/support systems) and underlying architectures and to define a high-confidence design.** All system elements (hardware and software) shall be at a level of maturity commensurate with the PDR entrance and exit criteria. **A successful PDR will inform requirements trades; improve cost estimation; and identify remaining design, integration, and manufacturing risks.** The PDR shall be conducted at the system level and include user representatives and associated certification authorities. The PDR Report shall be provided to the MDA at Milestone B and include recommended requirements trades based upon an assessment of cost, schedule, and performance risk.
Technology Readiness **Enclosure 2 Para 6c(4)**	Final Requests for Proposals (RFPs) for the EMD Phase, or any succeeding acquisition phase, shall not be released, nor shall any action be taken that would commit the program to a particular contracting strategy, until the MDA has approved the Acquisition Strategy. The PM shall include language in the RFP advising offerors that (1) the government will not award a contract to an offeror whose proposal is based on **CTEs that have not been demonstrated in a relevant environment**, and (2) that offerors will be required to **specify the technology readiness level of the CTEs** on which their proposal is based and to **provide reports documenting how those CTEs have been demonstrated in a relevant environment.**

These policies were further refined as a result of the WSARA of 2009. On December 4, 2009, The Honorable Dr. Ashton Carter, USD(AT&L) issued a Directive-Type Memorandum (DTM) 09-027—*Implementation of the Weapon Systems Acquisition Reform Act* that amended DoD Instruction 5000.02 (December 2, 2008). Specifically related to the competitive prototyping policy, DTM 09-027 directed,

> The technology development strategy (TDS) for each MDAP shall provide for prototypes of the system or, if a system prototype is not feasible, for prototypes of critical subsystems before Milestone (MS) B approval. Information technology initiatives shall prototype subsets of overall

functionality, with the intention of reducing enterprise architecture risks, prioritizing functionality, and facilitating process re-design.

In addition, DTM 09-027 provided for waivers to the competitive prototyping policy:

> a. The MDA may waive this requirement if: (1) The cost of producing competitive prototypes exceeds the expected life-cycle benefits (in constant dollars) of producing the prototypes, including the benefits of improved performance and increased technological and design maturity that may be achieved through competitive prototyping; or (2) The Department of Defense would be unable to meet critical national security objectives without such a waiver.
>
> b. If the competitive prototyping requirement is waived, the MDA shall require the program to produce a prototype before MS B approval if the expected life-cycle benefits (in constant dollars) of producing the prototype exceed the cost of the prototype and the production of the prototype remains consistent with national security objectives (e.g., when the initial operational capability must be fielded).
>
> (DoD, 2009, Attachment 1, pp. 4–5)

Regarding the PDR policy, DTM 09-027 directed that "PDRs before MS B are mandatory for all MDAPs and will be reflected in the TDS to be approved by the MDA at MS A. Post-PDR assessments will be conducted in association with MS B preparations and will be formally considered by the MDA at the MS B certification review" (DoD, 2009, Attachment 1, p. 9).

So, in addition to providing for prototype waivers, DTM 09-027 changed competitive prototyping and the requirement for a PDR before MS B from policy to a statutory mandate for all MDAPs.

Finally, DTM 09-07 provided a template for the Section 2366b of Title 10 certification required from the Milestone Decision Authority (MDA) to the Congress. By signing the certification memorandum, the MDA attests that various statutory requirements have been met by the program before entering the EMD phase. Among the sample language provided in DTM 09-027 are these statements related to the PDR and technology readiness (see Appendix A for TRL definitions):

> I have received the results of the preliminary design review and conducted a formal post-preliminary design review assessment, and certify on the basis of such assessment that the program demonstrates a high likelihood of accomplishing its intended mission.
>
> The technology in the program has been demonstrated in a relevant environment, as determined by the Milestone Decision Authority on the basis of an independent review and assessment by the Director of Defense Research and Engineering.
> (DoD, 2009, Attachment 3, pp. 16–17)

On November 26, 2013, The Honorable Frank Kendall, USD[AT&L] canceled DTM 09-027 after incorporating all of the statutory requirements of the WSARA of 2009 into Interim DoD Instruction 5000.02, *Operation of the Defense Acquisition System*.

It should be noted that 20 years before The Honorable John Young, USD[AT&L] mandated competitive prototyping for MDAPs, essentially the same requirement appeared in the September 1987 version of DoD Instruction 5000.2. That earlier mandate was termed

Competitive Prototyping Strategy (CPS) and was required for all MDAPs, if practicable (DoDI 5000.2, 1987). One impetus behind the mandate was the Packard Commission's recommendation to place "high priority on building and testing prototype systems to demonstrate that new technology can substantially improve military capability, and to provide a basis for realistic cost estimates prior to a full-scale development decision" (Packard, 1986, p. 55). If a CPS was not planned, the Congress had to be notified, in accordance with Section 2365, Title 10, United States Code (DoDI 5000.02, 1987, p. 7, paragraph F4). This CPS requirement lasted about five and a half years before it was canceled by Change 1 (February 26, 1993) to DoD Instruction 5000.2 (February 23, 1991). This was just a few months after Public Law 102-484 (October 1992) repealed the required use of a competitive prototyping strategy for MDAPS. The change appears to have been part of the wave of acquisition reforms that reflected the need to reduce post–Cold War defense spending.

Literature Review

An important work on prototyping in DoD weapon system development was published in 1992 by RAND. The author, Jeffery A. Drezner, constructed a database of programmatic information for 287 programs and surveyed 43 government program managers about their use of prototypes, from about 1960 through the late 1980s. He categorized how prototypes were used in support of various weapon system acquisition strategies. He specifically quantified cost growth and schedule slippage in aerospace programs from the Selected Acquisition Report (SAR) of December 1988. Drezner concluded that the relationships between prototyping and cost, schedule, and performance outcomes were "ambiguous due to the effect of confounding variables" (Drezner, 1992, p. 68). He could not find any significant statistical differences between outcomes from prototyping versus nonprototyping programs. Drezner did not recommend that DoD change its DoDI 5000.2 (February 23, 1991) policy mandating competitive prototyping for all major weapon systems. Rather, he recommended that each program manager weigh the costs and benefits of prototyping against the risks and consequences of proceeding into the next phase without the knowledge gained from prototypes (Drezner, 1992, pp. 59–67).

A more recent RAND study includes a chapter entitled "On Prototyping: Lessons from RAND Research." The authors, Jeffery A. Drezner and Meilinda Huang, summarize the work of some 30 papers and reports that deal directly with prototyping or touch on the subject. They define prototyping as "a conscious strategy to obtain certain types of information to inform specific decisions" (Birkler, 2010, p. 64). They review outcomes from both case studies and statistical analyses of prototyping and nonprototyping programs. While case studies provide mixed results, they conclude that statistical analyses show that programs applying prototyping knowledge prior to the development decision (today's Milestone B) experience less cost growth (Birkler, p. 76).

Since 2002, the Government Accountability Office (GAO) has undertaken an annual assessment of selected defense weapon programs. The GAO continues to advocate a knowledge-based acquisition approach. They assess the knowledge attained by each program in terms of requirements matching resources and maturity of technology prior to MS B, a stable design at the Critical Design Review (CDR), and capable and controlled production processes prior to MS C. In the past two years, these assessments have included a useful survey of selected programs in order to determine if policies, to include the policies discussed in the paper, are being followed.

There are two limitations inherent in the GAO assessments. First, by design, the assessments only address selected MDAP-level defense weapon system programs, and selected potential future MDAPs, not all programs. The 2012 GAO assessment looked at 37 out of 96 total MDAPs and 16 future potential MDAPs. The 2013 GAO assessment looked at 40 out of 86 total MDAPs and 17 future potential MDAPs. Second, the assessments are qualitative vice quantitative. Only limited statistical analyses are performed on the selected programs (GAO-12-400SP, 2012 and GAO-13-294SP, 2013).

There are numerous reports and publications with anecdotal references to the value of competitive prototyping to identify technology maturity and the importance of making requirements trade-offs at the preliminary design reviews. One such reference is instructive. Thomas Christie, who retired in 2005 after 4 years as the Director of Operational Test and Evaluation, is a vocal advocate of competitive prototyping and the other reforms in the WSARA of 2009. In his essay entitled, *Developing, Buying and Fielding Superior Weapon Systems*, Christie recommends that a "Fly-before-Decide" policy of competitive prototyping be mandated for all programs (not just MDAPs) before entering the EMD phase (Christie, 2011, pp. 121–122).

Research Methodology

Cost growth percentages for all MDAPs were obtained from Unit Cost Reports (UCR) included in Selected Acquisition Reports (SARs) from the years 2011 and 2012. All MDAPs submit an annual SAR, to include an UCR, to the Congress. To handle changes in procurement quantities over time, a unit cost number, Program Acquisition Unit Cost (PAUC), was used to determine cost growth. PAUC is calculated as follows:

$$PAUC = \frac{RDT\&E + Procurement + System\ specific\ Military\ Constuction\ costs}{Total\ number\ of\ fully\ configured\ end\ items\ procured\ (to\ include\ R\&D\ units)} \qquad (1)$$

The original PAUC, in base-year dollars, was taken from the UCR) submitted with the first annual SAR after MS B for development programs and MS C for production programs. *In either case, this original PAUC was determined after competitive prototyping and after PDRs, if those activities were part of the program's acquisition strategy.* This original PAUC was compared with the current UCR PAUC estimate, calculated to the same base-year dollars, and reported in the latest annual SAR (2011 and 2012). Thus, the cost growth percentage was determined as follows:

$$Percent\ Change\ to\ Date\ in\ PAUC = \frac{Current\ PAUC - Original\ PAUC}{Original\ PAUC}\ x\ 100\ \% \qquad (2)$$

In addition, the annual SARs identifies if programs have suffered an Acquisition Program Baseline (APB) threshold schedule breach. A program breaches its APB threshold schedule when its schedule slips beyond the number of months agreed to in the APB signed by the Program Manager and the MDA. For SAR reporting purposes, a schedule breach of 6 months or more from the baseline results in a reportable breach.

For the past two years, as part of its annual assessments of selected weapon programs, the Government Accountability Office (GAO) has conducted a survey of current and future Major Defense Acquisition Programs (MDAPs). The purpose of the survey is to determine if various acquisition reform policies and practices are being implemented. From the survey data, the GAO has been able to identify some programs that have demonstrated technology maturity on prototypes in a relevant environment (Technology Readiness Level 6) and have conducted a preliminary design review prior to Milestone B (GAO-12-400SP, 2012 and GAO-13-294SP, 2013). These programs are listed in Appendix B.

Descriptive statistics are used to analyze cost growth (percent change to date in PAUC) and schedule breaches for the MDAPs that have conducted competitive prototyping and PDR activities. Similar descriptive statistics are used to analyze the balance of the MDAPs included in a particular annual SAR submission. For example, there were 89 total MDAPs reported in the 2011 SAR submission. Of these MDAPs, 33 were identified by the GAO survey as having demonstrated technology maturity on prototypes in a relevant environment (TRL 6) and having conducted a PDR. The remaining 56 programs may or may not have used prototypes or achieved TRL 6 or conducted a PDR. The percentage of programs that have negative cost growth (negative percent change to date in PAUC) from each population is compared. The population with the highest number of negative cost growth programs is preferred. Similarly, the percentage of programs that suffered an APB schedule threshold breach from each population is compared. The population with the lowest percent of schedule breaches is preferred.

Results Analysis and Conclusion

Research results are summarized in Tables 2 through 5 of Appendix C.

PAUC Cost Growth Results. Based upon data from the 2011 SAR (Table 2), programs that demonstrated technology maturity on prototypes in a relevant environment (TRL 6) and conducted a preliminary design review prior to Milestone B *were more often to show negative PAUC cost growth.* Moreover, this result was seen in all DoD Components. Similar results were found in the data from the 2012 SAR (Table 3).

Caution is needed when interpreting these results. While all cost growth was measured from the original baseline, that baseline may have been different, depending on the point at which the program was initiated. Most programs establish their original baseline at the development decision, MS B. However, programs making use of non-developmental and commercial off-the-shelf items may be approved for program initiation at the production decision, MS C. Thus, the original baseline upon which cost growth is measured would also be established at MS C, vice MS B.

Cost growth was measured based upon the change in cost estimates, not actual costs. Cost estimates change for various reasons. The annual SAR reports (DoD, 2011 and DoD, 2012) show these categories of reasons for cost changes between the baseline and current cost estimates: quantity, schedule, engineering, support, estimating, and other. By using PAUC as the cost metric, this research has adjusted for changes in the cost estimates due to quantity. Cost changes due to schedule, engineering, and support could be directly attributable to the use of competitive prototypes to identify technology maturity and the use of a PDR prior to MS B. However, cost changes due to estimating would indicate that competitive prototyping and an early PDR did not help refine the cost estimate.

Schedule Threshold Breach Results. Based upon data from the 2011 SAR (Table 4), programs that demonstrated technology maturity on prototypes in a relevant environment (TRL 6) and conducted a preliminary design review prior to Milestone B *did not suffer fewer APB schedule threshold breaches.* Similar results were found in the data from the 2012 SAR (Table 5).

While the cost growth results seem to support the value of demonstrating technology maturity on prototypes (TRL 6) and conducting an early preliminary design review (before MS B), the schedule threshold breach results do not. There may be several reasons for this.

First, a reportable schedule breach is 6 months of schedule slippage from the previous SAR. All MDAPS must submit an annual SAR. And, if a unit cost or schedule breach occurs, the program must submit a SAR every quarter. So, a schedule breach is going to be reported relatively quickly after it occurs. In this research, the schedule breach metric only indicates that there was a schedule slippage of at least 6 months. The metric does not quantify the total number of months of slippage suffered by the program. Thus, if the two populations of programs were compared using the total months of schedule slippage, there might have been a different outcome.

Like cost estimates, baseline schedules are also estimates that can change for reasons other than execution performance of the development and production efforts. Funding availability can delay a development or disrupt production. For example, Warfighter Information Network-Tactical (WIN-T) Increment 3 breached its threshold schedule due to a decrement in the FY 2014 President's Budget (DoD, 2011). Alignment of supporting program schedules can also cause delays. For example, a 3-year slippage in the Initial Operational Capability (IOC) date for the Littoral Combat Ship (LCS) Mine Countermeasures Mission (MCM) package caused a reportable schedule breach for the MH-60S Multi-Mission Helicopter (DoD, 2011).

Finally, a comparison should be made between the earlier research by RAND based upon 1960-1980 program data (Drezner, 1992) and this research based upon 1990–2012 program data. Drezner's work was done in an era when defense acquisition programs were not required to use TRLs to assess the maturity of critical technologies. The DoD adopted TRLs from the National Aeronautics and Space Administration (NASA) and first introduced them as a tool for program managers in the early 2000s. In addition, prior to the 2008 version of DoD Instruction 5000.2, acquisition policy did not emphasize the importance of the PDR. DoD Instruction 5000.02 (2008) elevated oversight of the PDR by requiring a Post Preliminary Design Review Assessment (Post-PDRA) at the MDA level (DoD, 2008). This emphasis is certain to have caught the attention of program managers and motivated them to pay more attention to technology readiness and PDR policies. Perhaps this recent emphasis has had an effect on reducing cost growth and schedule slippages in the programs used in this research.

Recommendations for Further Research

It is doubtful that the USD[AT&L] will ever be able to truly determine the effect of the competitive prototyping, technology readiness, and early PDR policies on program cost growth or schedule slippage. As Drezner said, "One fundamental problem is that while we can examine prototyping programs, or compare the outcomes of prototyping and nonprototyping programs, the outcome for the same program with and without prototyping can never be known" (Drezner, 1992, p. 59). However, there are some things that can be done to improve the imperfect research to date.

First, to determine cost growth, compare PAUC based upon the original cost estimate with actual PAUC. Actual PAUC can be determined from contracts found in the Defense Cost and Resource Center (DCARC) database. The percentage of growth from the PAUC based upon the original cost estimate (at program initiation) and the actual PAUC (at the end of the development and production program) would remove some of the uncertainty in this metric.

Second, to determine schedule slippage, compare the original schedule estimate with actual schedule performance data. Again, the actual schedule performance data for this comparison should be available in the DCARC database or Defense Acquisition Management Information Retrieval (DAMIR). The percentage of growth from the original schedule estimate to the actual schedule performance would remove some of the uncertainty in this metric.

Finally, the challenge in using cost growth and schedule slippage metrics is to tie them back to the use of competitive prototyping (to reveal technology readiness) and the use of an early PDR. Drezner said that prototyping is “a conscious strategy to obtain certain types of information to inform specific decisions” (Birkler, 2010, p. 64). The same can be said for technology readiness and PDRs. The knowledge from these activities and how that knowledge is applied will tell us whether these policies have had an effect. To that end, more detailed surveys, such as those conducted annually on selected weapon systems by the GAO, will aid in helping establish the cause-effect relationship between policy and program outcomes.

References

Assistant Secretary of Defense for Research and Engineering (ASD[R&E]). (2011, April). *Technology Readiness Assessment (TRA) Guidance.* Washington, DC: Author.

Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA[AL&T]). (2008, January 2). *Army Prototyping and Competition* [Memorandum]. Washington, DC: Author.

Birkler, J., Arena, M.V., Blickstein, I., Drezner, J.A., Gates, S., Huang, M., Murphy, R., Nemfakos, C., & Woodward, S. (2010). *From Marginal Adjustments to Meaningful Change: Rethinking Weapon System Acquisition.* Santa Monica, CA: RAND.

Christie, Thomas. (2011). *Developing, Buying and Fielding Superior Weapon Systems.* Essay 10 in *The Pentagon Labyrinth: 10 Short Essays to Help You Through It*. Windslow T. Wheeler, ed. Washington, DC: Center for Defense Information. Retrieved from http://pogoarchives.org/labyrinth/full-labyrinth-text-w-covers.pdf

DoD. (1987, September 1). *Defense acquisition program procedures* (DoDI 5000.2). Washington, DC: U.S. Government Printing Office. Retrieved from http://www.whs.mil/library/mildoc/DODD.html

DoD. (1991, February 23). *Defense acquisition management policies and procedures* (DoDI 5000.2). Washington, DC: U.S. Government Printing Office. Retrieved from http://www.whs.mil/library/mildoc/DODD.html

DoD. (2008, December 8). *Operation of the defense acquisition system* (DoDI 5000.02). Washington, DC: U.S. Government Printing Office.DoD. (2013, June 28). *Defense Acquisition Guidebook.* Retrieved from https://dag.dau.mil

DoD. (2011, March 31). *Selected Acquisition Reports December 2011.* Retrieved from http://www.dod.mil/pubs/foi/logistics_material_readiness/acq_bud_fin/SARs.html

DoD. (2012, March 31). *Selected Acquisition Reports December 2012.* Retrieved from http://www.dod.mil/pubs/foi/logistics_material_readiness/acq_bud_fin/SARs.html

DoD. (2013, November 26). *Operation of the defense acquisition system* (Interim DoDI 5000.02). Washington, DC: U.S. Government Printing Office.

Drezner, Jeffery A. (1992). *The Nature and Role of Prototyping in Weapon System Development* (R-4161-ACQ). Santa Monica, CA: RAND.

GAO. (2012, March). *Defense acquisitions: Assessments of selected weapon programs* (GAO-12-400SP). Retrieved from GAO website: http://www.gao.gov

GAO. (2013, March). *Defense acquisitions: Assessments of selected weapon programs* (GAO-13-294SP). Retrieved from GAO website: http://www.gao.gov

Packard, David. (1986, June 30). *A Quest for Excellence: Final Report to the President by the President’s Blue Ribbon Commission on Defense Management.* Retrieved from http://www.dtic.mil/docs/citations/ADA170887

Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]). (2007, September 19). *Prototyping and Competition* [Memorandum]. Washington, DC: Author.

Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]). (2013a April 22). *Implementation Directive for Better Buying Power 2.0—Achieving Greater Efficiency and Productivity in Defense Spending* [Memorandum]. Washington, DC: Author.

Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]) . (2013b, June 28). *Performance of the Defense Acquisition System, 2013 Annual Report.* Washington, DC: Author.

Weapon System Acquisition Reform Act of 2009 (Public Law 111-23). § 201. Consideration of trade-offs among cost, schedule, and performance objectives.

Weapon System Acquisition Reform Act of 2009 (Public Law 111-23). § 203. Prototype requirements for major defense acquisition programs.

Appendix A. Technology Readiness Level (TRL) Descriptions

(Defense Acquisition Guidebook, 2013**,** para. 10.5.2.2)

Technology Readiness Level	Description
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Appendix B. Programs Identified as Using Competitive Prototyping and Preliminary Design Reviews (PDR)

GAO-12-400SP (33 Programs)	Component
AGM-88E Advanced Anti-Radiation Guided Missile (AARGM)	USN
Apache Block IIIA (AB3A) Remanufacture	USA
Airborne and Maritime/Fixed Station Joint Tactical Radio System (AMF JTRS)	DoD
B-2 Extremely High Frequency SATCOM Capability, Increment 1	USAF
C-130 Avionics Modernization Program (AMP)	USAF
CH-53K Heavy Lift Replacement (CH-53K)	USN
DDG 1000 Zumwalt Class Destroyer	USN
E-2D Advanced Hawkeye (AHE)	USN
Excalibur Precision 155mm Projectiles	USA
Family of Advanced Beyond Line-of-Sight Terminals (FAB-T)	USAF
Global Positioning System (GPS) III	USAF
HC/MC-130 Recapitalization Program	USAF
Integrated Air & Missile Defense (IAMD)	USA
Integrated Defensive Electronic Countermeasures (IDECM) Block 4	USN
Joint Air-to-Surface Standoff Missile (JASSM Baseline)	USAF
Joint Air-to-Surface Standoff Missile (JASSM-Extended Range)	USAF
Joint High Speed Vessel (JHSV)	USN
Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS)	USA
Joint Precision Approach and Landing System (JPALS)	USN
LHA 6 America Class Amphibious Assault Ship	USN
Littoral Combat Ship (LCS)—Seaframes	USN
Mobile User Objective System (MUOS)	USN
MQ-1C Unmanned Aircraft System (UAS) Gray Eagle	USA
MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)	USN
MQ-9 Unmanned Aircraft System (UAS) Reaper	USAF
Navy Multiband Terminal (NMT)	USN
P-8A Poseidon	USN
RQ-4A/B Global Hawk Unmanned Aircraft System	USAF
Small Diameter Bomb Increment II (SDB II)	USAF
Standard Missile-6 (SM-6)	USN
Vertical Takeoff and Landing Tactical Unmanned Aerial Vehicle – MQ-8 Fire Scout (VTUAV)	USN
Warfighter Information Network-Tactical (WIN-T) Increment 2	USA
Warfighter Information Network-Tactical (WIN-T) Increment 3	USA

GAO-13-294SP (34 Programs)	Component
AH-64E Apache Remanufacture	USA
AIM-9X Block II Air-to-Air Missile	USN
AN/TPS-80 Ground/Air Task Oriented Radar (G/ATOR)	USN
CH-53K Heavy Lift Replacement (CH-53K)	USN
DDG 1000 Zumwalt Class Destroyer	USN
E-2D Advanced Hawkeye (AHE)	USN
Excalibur Precision 155mm Projectiles	USA
Family of Advanced Beyond Line-of-Sight Terminals (FAB-T)	USAF
Gerald R. Ford Class Nuclear Aircraft Carrier (CVN 78 Class)	USN
Global Positioning System (GPS) III	USAF
HC/MC-130 Recapitalization Program	USAF
Integrated Air & Missile Defense (IAMD)	USA
Integrated Defensive Electronic Countermeasures (IDECM) Block 4	USN
Joint Air-to-Surface Standoff Missile (JASSM Baseline)	USAF
Joint Air-to-Surface Standoff Missile (JASSM-Extended Range)	USAF
Joint High Speed Vessel (JHSV)	USN
Joint Precision Approach and Landing System (JPALS)	USN
Joint Tactical Radio System (JTRS) Handheld, Manpack, and (HMS) Small Form Fit Radios	USA
KC-46A Tanker Modernization Program	USAF
LHA 6 America Class Amphibious Assault Ship	USN
Littoral Combat Ship (LCS)—Seaframes	USN
Mobile User Objective System (MUOS)	USN
MQ-1C Unmanned Aircraft System (UAS) Gray Eagle	USA
MQ-4C Triton Unmanned Aircraft System (MQ-4C Triton)	USN
MQ-9 Unmanned Aircraft System (UAS) Reaper	USAF
Navy Multiband Terminal (NMT)	USN
P-8A Poseidon	USN
Paladin/Field Artillery Ammunition Support Vehicle (FAASV) Integrated Management (PIM)	USA
RQ-4A/B Global Hawk Unmanned Aircraft System	USAF
Ship to Shore Connector (SSC)	USN
Standard Missile-6 (SM-6)	USN
Vertical Takeoff and Landing Tactical Unmanned Aerial Vehicle – MQ-8 Fire Scout (VTUAV)	USN
Warfighter Information Network-Tactical (WIN-T) Increment 2	USA
Warfighter Information Network-Tactical (WIN-T) Increment 3	USA

Appendix C. Results of Research

Table 2. Programs Costing Less, Selected Acquisition Report, December 31, 2011

Component	Programs w/Prototypes & PDR			Balance of Programs		
	Programs Costing Less	Total Programs	Percent	Programs Costing Less	Total Programs	Percent
Army	6	7	86	3	12	25
Navy	7	15	47	6	20	30
Air Force	5	10	50	4	15	27
Def Agency	1	1	100	2	9	22
Total	**19**	**33**	**57**	**15**	**56**	**27**

Table 3. Programs Costing Less, Selected Acquisition Report, December 31, 2012

Component	Programs w/Prototypes & PDR			Balance of Programs		
	Programs Costing Less	Total Programs	Percent	Programs Costing Less	Total Programs	Percent
Army	5	8	62	4	12	33
Navy	8	18	44	4	20	20
Air Force	3	8	38	6	17	35
Def Agency	0	0	0	4	5	80
Total	**16**	**34**	**47**	**18**	**54**	**33**

Table 4. Program Schedule Breach, Selected Acquisition Report, December 31, 2011

Component	Programs w/Prototypes & PDR			Balance of Programs		
	Programs w/Schedule Breach	Total Programs	Percent	Programs w/Schedule Breach	Total Programs	Percent
Army	2	7	28	2	12	17
Navy	4	15	27	5	20	25
Air Force	4	10	40	6	15	40
Def Agency	1	1	100	4	9	44
Total	**11**	**33**	**33**	**17**	**56**	**30**

Table 5. Program Schedule Breach, Selected Acquisition Report, December 31, 2012

Component	Programs w/Prototypes & PDR			Balance of Programs		
	Programs w/Schedule Breach	Total Programs	Percent	Programs w/Schedule Breach	Total Programs	Percent
Army	3	8	38	4	12	33
Navy	6	18	33	3	20	15
Air Force	2	8	25	7	17	41
Def Agency	0	0	0	0	5	0
Total	**11**	**34**	**30**	**14**	**54**	**26**

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