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**IMPACT OF CONTINUOUS COMPETITION
ON OPERATIONS AND SUPPORT COSTS**

by

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Executive Summary

Based on projected federal budget deficits, the Department of Defense can expect continued downward budgetary pressure for the foreseeable future. Necessary spending, such as replacing aging defense systems and providing health care for veterans and their families, makes the DoD's long-term acquisition plans unsustainable. If current spending patterns continue, then cost control, not to mention net budget cuts, will be one of the most difficult challenges facing defense policymakers. Under intense pressure to cut the defense budget following the end of major hostilities in Iraq, Secretary of Defense Robert M. Gates has acknowledged that the era of unchallenged defense spending is over (Shanker, 2010). As large numbers of U.S. forces remain engaged in winning the peace in Iraq and Afghanistan, it is essential that the DoD work to reduce inefficiencies and set priorities, as it faces an inevitable drawdown.

One of the challenges to any DoD budget analyst is determining the net cost of defense systems. This is not a simple task. To the casual observer who follows press announcements of new defense systems, the overriding factor is procurement cost. Indeed, these costs are the most straightforward: \$5 to \$7 billion for a *Nimitz* class aircraft carrier, \$1 billion for an *Arleigh Burke* guided missile destroyer, and so on. These costs may seem large, but they shrink in comparison to the costs of owning, operating, maintaining, and supporting these ships. Over its 50-year lifetime, the *Nimitz* class aircraft carrier's operations and support (O&S) costs are nearly \$30 billion. For major defense systems, like ships, aircraft, and tanks, the O&S costs account for 65% to 70% of total life-cycle costs, which refers to the total amount spent on a defense system for planning, R&D, testing, production, O&S, and disposal. O&S costs may be large, but they are frequently not a driving factor in the design of new defense systems. By not making critical O&S cost-reducing decisions in the design stage of the acquisitions process, the total costs of defense systems become unsustainable for the nation.

Another challenge to improving contract outcomes is the defense market structure. The defense market is unusual in that there is only one buyer and just a handful (or less) of potential sellers in each product area. Frequently, the government awards single-source

contracts in which there is limited or, in many cases, no competition. When there is little to no competition, the government enjoys the market power as the single buyer (monopsonist), whereas the defense contractor enjoys the market power as the single seller (monopolist). Despite the government's monopoly on demand, it is difficult to force defense contractors to set priorities, such as cost reduction and performance improvements.

One successful approach to reducing both procurement and O&S costs is to introduce greater competition to the defense market. The DoD has, at various times, shown its willingness to introduce competition in each stage of the acquisitions process, enabling what may be termed "continuous competition" in select programs. Still, it is worth stressing that the DoD generally does not support competition through dual-sourcing in the production stage. There is widespread agreement that greater competition for defense contracts results in improved performance, lower costs, and greater responsiveness to government concerns. One of the key questions for this report is whether expanding the use of competition in the production stage will result in similar net gains for the government, particularly during the O&S phase.

Competitive dual-sourcing describes the practice of using two firms to produce an identical or substitutable good in a competitive environment. The goods may be identical, such as build-to-print production awards, or substitutable, like the two classes of littoral combat ships (LCS). For dual-sourcing to be competitive, there must be a market mechanism that rewards successful firms, typically by awarding them a larger portion of the subsequent contract award's total lot. By extension, unsuccessful firms receive a smaller portion of the total lot, providing a powerful disincentive for poor performance.

There are several barriers to expanding the use of competitive dual-sourcing in the defense market, including several laws and regulations, but the most serious is conceptual misunderstanding. Traditional learning curve theory explains how firms become more efficient at producing a good as they produce more of it. This theory suggests that single-sourcing would be more efficient than second or competitive dual-sourcing because the

sole producer gets volume. Thus, critics of dual-sourcing see the second source of dual-sourcing as wasteful spending. If dual-sourcing is implemented, and one firm performs better, then critics would question why that firm should not have been chosen as the single source. This criticism reflects a common misunderstanding that firms behave similarly under competitive and non-competitive market conditions. Considerable research of contract outcomes, however, suggests just the opposite: competitive market pressure from competitive dual-sourcing forces firms to move down the learning curve faster, while sole-sourcing usually results in flat or rising learning curves as firms take advantage of program changes (which usually come along and can be quoted in a sole-source environment).

A second conceptual problem is that the benefits of competitive dual-sourcing are less certain than the costs of maintaining a second line of production. Despite the considerable body of evidence that suggests that competitive dual-sourcing has the potential for significant cost reduction, risk-adverse policymakers may not be enthusiastic when other worthy programs go unfunded.

Findings

After analyzing case studies in which competitive dual-sourcing has been used for three kinds of defense systems (missiles, aircraft engines, and littoral combat ships), we found that the DoD has, at times, utilized competitive dual-sourcing appropriately and effectively. After introducing a second source, the DoD has generally achieved positive results: improved quality, reduced overall costs, and greater responsiveness to government concerns. O&S costs were reduced primarily through quality improvements that reduced the need for maintenance, reduced manpower needed to operate systems, and extended unit life expectancy. The magnitude of the benefits from competitive dual-sourcing varies by defense system type, production quantity, and firm experience, but on average, the benefits are quite significant (e.g., net cost savings of over 30%).

First, the type of defense system is important because the benefits of competitive dual-sourcing vary from system to system. Generally, defense systems and subsystems that have high O&S costs will produce greater savings when awarded as dual-sourced

contracts. Jet engine competitions, like “the great engine war” (i.e., dual-sourcing engines for the F-15 and F-16), are an excellent example of how subsystems with high O&S costs can produce large savings. Defense systems with low O&S costs may not produce savings as dramatic as those of an engine competition, but their benefits from competitive dual-sourcing may also be significant. Missiles with build-to-print production contracts witnessed substantial decreases in O&S costs through quality improvements. Higher quality defense systems need to be tested and replaced less often, reducing total program cost.

The type of defense system is also important because many defense systems have commercial equivalents. Defense systems that have commercial equivalents are prime candidates for competitive dual-sourcing because the additional costs for maintaining a second line of production (and O&S) would be minimal.

Second, defense systems that are needed in large quantities are also more suitable for competitive dual-sourcing because their economies of scale make unit costs lower when production quantities are high.

Finally, competitive dual-sourcing can be used effectively to expand the base of the defense industry. The relatively limited number of firms in the defense industry (in each sector) reduces competition because firms with experience producing a particular defense good enjoy an initial competitive advantage, thus creating a barrier to entry for new firms (as well as encouraging the “loser” firms to exit, reducing future competition).

In this study we identify several candidate programs for competitive dual-sourcing and encourage the DoD to consider expanding the use of competitive dual-sourcing.

Moreover, in this study we also identify several current barriers (legislative, regulatory, policy) to expanded use of competitive dual-sourcing and make several recommendations for how Congress and the DoD can work together to achieve superior results through acquisition reform.

Recommendations

- The Under Secretary of Defense for Acquisition, Technology, and Logistics should encourage greater use of competitive dual-sourcing.
- Whenever possible, the DoD should reserve the right to add a second source and convert to a competitive dual-source contract to ensure that the contractor provides best effort and responsiveness to DoD queries, requests, and requirements.
- When using competitive dual-sourcing, the DoD should address cost growth and quality concerns through the adoption of manufacturer warranties and post-production incentives, preferably in the development phase.
- The DoD must overcome internal barriers to embrace the Weapon Systems Acquisition Reform Act of 2009, specifically its competition clauses.
- Competitive dual-sourcing contracts should provide firms proper incentives to prioritize low-cost designs.

Conclusion

Increasing pressure on defense policymakers to cut the DoD's fiscal year (FY) 2012 budget represents a unique opportunity to reevaluate the way in which the DoD acquires defense systems. As our allies grow increasingly dependent on American military capabilities for enhancing international security, it is critical that America reduce the size of its defense budget in a responsible manner. Reforming defense acquisitions by expanding the use of competitive dual-sourcing provides a long-term source of savings to the DoD without sacrificing needed military capabilities.

Competitive dual-sourcing has the potential to reduce production costs and O&S costs by incentivizing contractors to work more efficiently and to invest in quality and reliability improvements, all of which enables the government to do more with less. By enabling continuous competition, defense contractors can capitalize on the same efficiency gains

and performance improvements that firms in the private sector (in a continuous-competitive environment) routinely provide each other. The DoD may be in a budgetary crisis, but it is also facing an opportunity for meaningful acquisitions reform that should not be left to waste.

I. Introduction

The Department of Defense's acquisition system has consistently delivered some of the world's most capable defense systems to the men and women of the United States Armed Forces. At the same time, the acquisition system is routinely criticized for its continued inability to adhere to program cost estimates. In contrast to many contracts between firms in the private sector, the DoD's contracts generally grow more expensive with time. Even when compared to initial estimates, DoD acquisitions are frequently more expensive and less capable than originally projected. Moreover, systems acquisitions may be fraught with costly delays that have potentially serious consequences for warfighters overseas.

As the U.S. federal government struggles to reduce its deficit spending, Congress and the executive branch are eager to realize potential savings from the DoD's large budget. The objective of this study is to determine the effect of continuous competition on the net costs of defense systems. Continuous competition refers to the notion that competition exists in each phase of the acquisitions process: technology development, engineering and development, production and deployment, and operations & support (O&S). The DoD, when it does increase competition, generally does so in one of the phases other than production. Yet production and the subsequent O&S phase represent the overwhelmingly largest share of the total production costs. Reforming the acquisitions process by introducing greater levels of competition in the production phase has the potential to not only control expected cost growths but also, in fact, reduce them. Before exploring options to realize potential cost savings, it is important to analyze the source of the defense systems' cost growth.

Background to Defense Acquisitions

To acquire needed defense systems and services from the private sector's defense contractors, the DoD follows a well-regulated process with scheduled meetings, performance evaluations, reports, and decision points. Although this process appears unnecessarily slow and complex to an outside observer, it is important to keep in mind that the acquisitions process is designed to balance a number of priorities. The clearest and most obvious priority is the need to provide the DoD with high-quality defense systems that meet the needs of our military and supporting civilian agencies. As important as this priority is, the defense acquisitions process also

accomplishes a number of other objectives, such as transparency, government accountability, fair practices towards the private sector, and several socioeconomic objectives.

While many defense programs experience competition at some stage of the defense acquisition process, the DoD has generally incorporated competition in only the first three stages of system acquisition (material solution analysis, technology development, and engineering/development), which make up a small percentage of the overall system acquisition cost. Efforts to increase competition in the production and O&S phases have been limited. For many defense systems, the DoD provides incentives for firms to provide their best effort by promising to award the most competitive bidder a winner take all (WTA), single-source production award. The award for production was seen as the real payoff because such an award provided a stable, long-term source of revenue for the company. In contrast, the earlier phases of the acquisitions cycle have greater program risk because the government could inject competition or cancel the program while assuming a small amount of loss.

If the DoD were to maintain competition in every stage of the acquisitions process, it would be implementing “continuous competition.” Continuous competition has the potential to reduce program costs and improve contract outcomes in every stage of the acquisitions process. In an era in which the cost growth of DoD programs has become a national security issue, continuous competition deserves more attention as an approach to produce better performing systems, while reducing procurement and O&S costs.

Cost Growth

The average major defense program—which typically enters the production phase as sole-source—continues to experience significant cost growth. For example, the programs that comprised the DoD’s Major Defense Acquisition Projects (MDAPs) for 2007 had an average cost growth of 26% when compared to initial estimates, which collectively produced \$295 billion in unanticipated costs (Sullivan, 2008). A more recent report found that over half of the total cost growth of the DoD’s major defense acquisition program portfolio over the last two years was driven by 10 of the DoD’s largest programs, which are all in production (Sullivan, 2011).

A number of reports published between 1959 and 2006 tracked programs in the acquisition cycle between 1948 and 2003 and reported similar outcomes, as shown in Figure 1. In addition, two prominent longitudinal studies that tracked cost growth over time produced the same finding (Tyson, Om, Gogerty, Nelson, & Utech, 1992; Younossi, 2007).

Overall, the reports all came to the similar conclusion that “the analysis indicates a systematic bias toward underestimating the costs and substantial uncertainty in estimating the final cost of a weapon system” (Arena, 2006). Although the studies differed in their cost growth estimates, it is clear that high cost growth has been a systemic problem in DoD acquisitions since its creation in 1947.

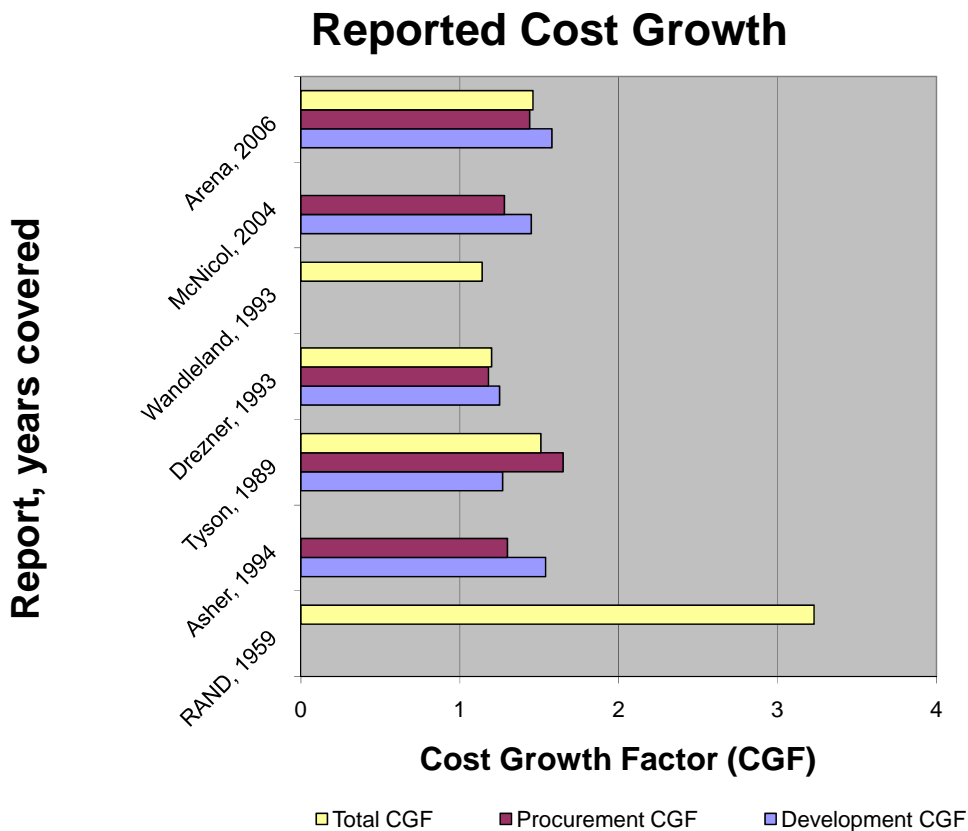


Figure 1: Graphical Results of Past Cost Growth Reports
 Source: (Younossi, 2007)

Cost Growth in a Defense Program’s O&S Phase

O&S refers to all the costs of operating, maintaining, and supporting fielded systems as incurred from the initial deployment to the end of their service life. O&S costs are an integral part of the

DoD's total annual expenditures—nearly 40% of the DoD's FY2009 budget was appropriated for O&S. For a typical weapon system, the O&S costs account for the majority of an individual program's life-cycle costs (Gansler, 1989). According to a recent DoD report by the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]), the O&S costs for current weapons systems may be even higher, over 70% of a system's total life-cycle costs (Carter, 2009).

The DoD expects O&S costs to continue to grow for two reasons. First, the current conflicts in Iraq and Afghanistan have resulted in longer overseas deployments, as well as in a higher operations tempo (resulting in greater use of military systems). Under these conditions, maintenance needs increase. Moreover, these deployed systems occasionally miss routine maintenance, due to operational necessity, and then require substantially more maintenance when they are available to be serviced. Second, delays in fielding new systems have caused current systems to remain in operation longer than anticipated. For instance, most of the ground vehicles currently used in the field were first designed and produced in the 1970s. As systems age, they become costlier to maintain—not only increasing O&S costs today, but also reducing the funds that are available for modernization programs that would allow the DoD to lower O&S costs in the future. This second issue has been such a concern that in 2000, one author of this study (Dr. Jacques Gansler, then the USD[AT&L]), stated before Congress that defense acquisition was in a death spiral—“a situation where reduced readiness requires us to keep removing more and more dollars from equipment modernization and putting it into daily [maintenance costs], thus further delaying modernization, causing the aging equipment to be over-used, further reducing readiness, and increasing [maintenance costs]—a vicious circle” (Program Manager, 2000). With future budgets likely to shrink, the DoD must make some difficult decisions to maintain military readiness in a sustainable manner. Rising O&S costs, as well as expected budget cuts, threaten the DoD's ability to field state-of-the-art weapons systems in support of national security objectives.

Moreover, the previously cited reports on cost growth for DoD defense programs failed to capture the total cost growth because these reports base their conclusions on data provided by the Selected Acquisition Reports (SARs). These reports are intended to include a full life-cycle cost analysis for the designated major defense acquisition program that is in the system development

stage or has just completed that stage (Title 10, Subtitle A, Part IV, Chapter 144, § 2432). Thus, three problems arise from using SARs with regards to O&S costs: (1) SAR data have exhibited inconsistencies over time (e.g., regarding changes in quantity, scope, budget, etc.), (2) “very few MDAPs include acquisition-related operations and maintenance funding” (Arena, 2006), and (3) programs submit a final SAR when either 90% of the program’s funds are expended or 90% of products are delivered—which is likely to occur long before the disposal of the system (Axtell, 2008). Consequently, when compared to cost growth in earlier phases, cost growth in the O&S phase tends to be underreported and poorly understood.

Several other studies have concluded that many programs experience significant cost growth during the O&S phase but, due to limitations in data collection, were unable to make assertions across the DoD. For example, one study of 26 Navy systems found an average O&S cost growth of 15%, with many of the programs still deployed (Choi, 2009). A more limited GAO study of five fielded weapons found that the systems “had experienced growth in their operating and support cost estimates of between 16 and 48 percent within the last 12 years, and problems with reliability once in the field” (GAO, 2003).

DoD Efforts to Combat Cost Growth

Cognizant of rising O&S costs, the DoD has made several attempts to curtail cost growth. As early as the 1970s, the DoD began “to emphasize life-cycle costs, reliability, and maintainability ... [so that it could field systems that] would be more affordable to operate and maintain” (Devers & Salerno, 1993). Recently, the DoD has begun implementing incentives that reward contractors for reducing life-cycle costs. While these contracts are new and have not yet entered the full-scale production phase, they represent the beginning of a cultural change in how the DoD plans acquisitions. Analysis of the effectiveness of these new contracts’ metrics is still years away, but significant cost savings are expected.

In response to the Weapon Systems Acquisition Reform Act (WSARA) of 2009, the DoD undertook reforms to improve the accuracy of their cost estimates for major defense acquisition programs (Levin, 2009). These reforms include the following:

- a) establishing the office of Cost Assessment & Program Evaluation (CAPE),

- b) evaluating the maturity of technologies used in defense systems in the planning and development phases,
 - c) testing defense systems more thoroughly during the development phase,
 - d) expanded use of independent cost assessments,
 - e) requiring completion of Preliminary Design Review (PDR) and a formal post-PDR assessment prior to Milestone B approval,
 - f) expanded use of competition throughout the life cycle, and
 - g) greater scrutiny of defense programs that experience a Nunn–McCurdy cost breach.
- (Levin, 2009)

Cost Reduction Through Competition

Competition drives decision-making in market economies, as it provides market pressure and incentives that encourage firms to increase economic efficiency, pursue greater innovation, and improve quality and performance. In many ways, the defense industry does not resemble a competitive market economy. There is generally only one consumer (the DoD) and there are very few producers (defense contractors) in each sector. By introducing more competition into the awarding of defense contracts, particularly during the production phase, the U.S. government can receive better value for its defense spending. In addition to better value, the government also benefits from increased competition by enhancing the responsiveness of contractors to changing government concerns (e.g., regarding mission changes, new technology introduction, budget shifts, etc.) as well as by expanding the defense industrial base to enable long-term defense industry competitiveness.

Congress first mandated the use of competition for federal acquisitions with the Competition in Contracting Act (CICA) of 1984. Since then, numerous federal government laws and guidelines as well as DoD directives have attempted to expand the use of competition in the awarding of government contracts.

Presidential administrations have similarly supported expanding the use of competition in defense acquisition. In March 2009, President Obama stated that “we need more competition for contracts and more oversight when they are carried out” (Bennett & Muradian, 2009).

Hypothesis

Introducing more competition in the production phase of the acquisitions process could significantly reduce O&S costs, but the decision to do so should be made on a case-by-case basis. Although the DoD would incur some additional upfront costs in these select programs, the reductions in procurement and O&S cost would be more than large enough to justify the investment in competitive dual-sourcing. An individual program's suitability for competitive dual-sourcing depends on the production quantity and cost of developing and maintaining a second production line. Competitive dual-sourcing may also make sense on critical (high cost, low reliability, high maintenance, etc.) subsystems, which typically make up over 70% of a weapon system's production and maintenance costs. If the production quantity is too small, or the costs of a second production line are too high, then it may not be possible for the life-cycle cost reductions to recover the initial investment. Although competition in the production stage is not always feasible, the DoD could reap large dividends from utilizing more competition in the production phase to reduce a system's overall life-cycle costs.

For this study, we have examined two types of cases: programs that started as single-source but later experienced competitive dual-sourcing (leader-follower), and programs that experienced competition throughout the acquisitions process.

II. The DoD Acquisition Cycle

The DoD's defense acquisition cycle is composed of five primary phases: materiel solution analysis, technology development, engineering and manufacturing development, production and deployment, and operations and support. Together, these phases represent the life cycle of a system. Defense acquisition is generally a long and complex process.

A simplified version of the DoD's Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System is shown in Figure 2. There are three milestones represented by triangles and assigned the letters A, B, and C. Each milestone decision requires a variety of assessments. These assessments are numerous and can be quite time-consuming to perform, and they span topics that include an Analysis of Alternatives (AoA), Independent Cost Estimates, Logistics/Repair Estimates, Life Cycle Sustainability, and other reports that confirm a program's adherence to regulation on subjects like technology issues, data management, and other acquisitions issues (Defense Acquisition University, Information Systems Service Center, 2010; Edward Aldridge, 2003). Actual reporting requirements vary between types of programs.

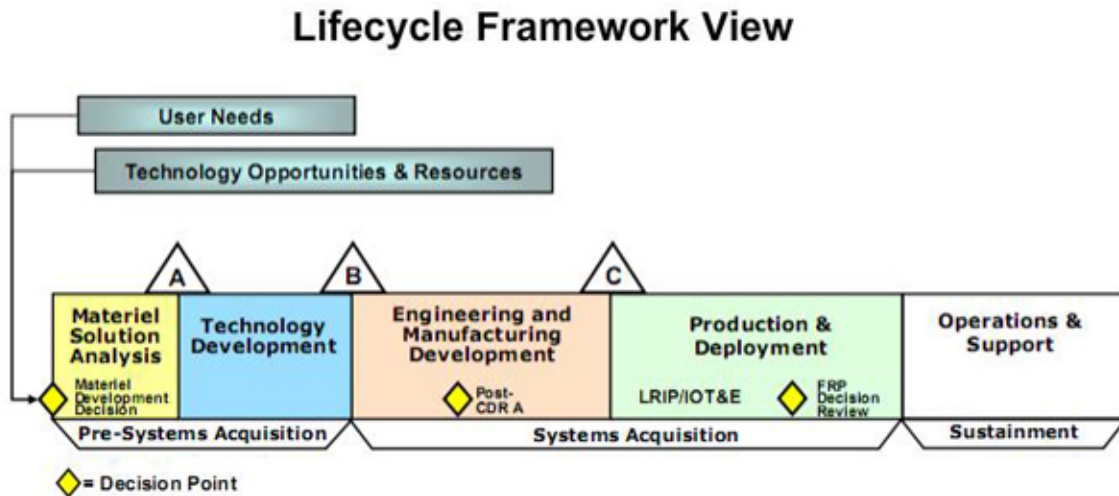


Figure 2: The DoD's Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System
 Source: (Defense Acquisition University, Information Systems Service Center, 2010)

The length of time a program spends in a given acquisition phase, as well as the percentage of the total cost of the program spent for a given acquisition phase, depends on the program in question. “[T]he total time, from the conception of a weapon system through the initial

deployment of a small quantity, is in the range 11 to 19 years” (Gansler, 1989). Full-scale production may require an additional 10 years, and the length of the O&S phase is largely determined by the system’s lifespan (for major defense systems, like B-52 and M1A2, the lifespan can stretch 50–70 years; GAO, 2003). Some types of programs, such as munitions, have very high front-end costs but low O&S costs. Conversely, other programs, such as ground vehicles, have relatively low front-end costs and significant back-end costs.

As a result, for most DoD weapon systems, the O&S costs are typically the highest portion of the ownership cost because they represent the cost to operate the system for many years (often 30 years or more). As shown in Figure 3, these costs, on average, constitute 72% of the total ownership cost of a weapon system. While 72% of the life-cycle cost of a weapon system is realized only after it is fielded, the decisions made early in the acquisition process have a disproportionate impact upon later cost expenditures.

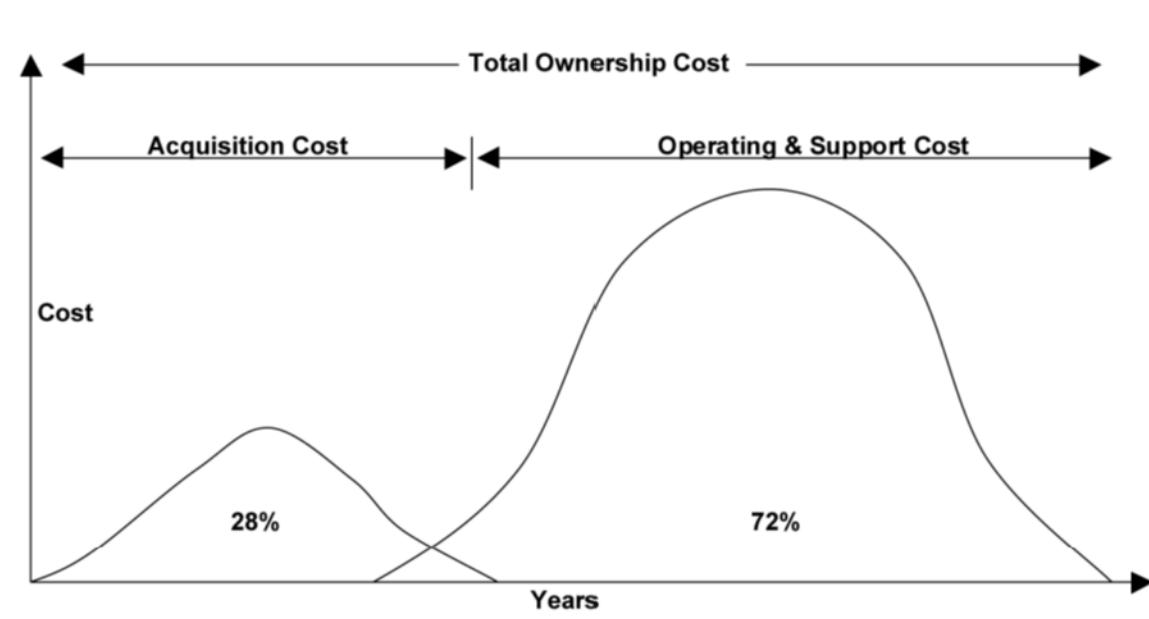


Figure 3: Nominal Life-Cycle Cost of Typical DoD Acquisition Program With a 30-Year Service Life
Source: (GAO, 2003)

While decisions made in the first four phases of the acquisitions process have a disproportionate effect on O&S costs, the timing of those decisions is important as well. Slight delays or higher investment in the first four phases of the acquisitions process may prevent much more painful

adjustments during the O&S phase. Given the importance of early decisions, it is vital for a program manager to weigh short-term and long-term implications of decisions before selecting a course of action, in order to avoid a “penny-wise but pound-foolish” outcome.

Operations & Support Phase

The final phase of the life cycle, and typically the longest, is operations and support. This phase reflects all of the costs required to maintain serviceable systems, including “the costs (organic and contractor) of personnel, equipment, supplies, software, and services associated with operating, modifying, maintaining, supplying, training, and supporting a system in the DoD inventory” (Cost Analysis Improvement Group, 2007). This stage ends with the disposal of the system at the end of its service life. The O&S phase often overlaps significantly with the production and deployment period.

O&S costs are an integral part of the DoD’s total yearly expenditures. On an individual program level, the operations and support costs account for the majority of a system’s total life-cycle expenditures. As shown in Figure 3, the Government Accountability Office (GAO) estimates that O&S costs comprise 72% of a typical (non-space, non-munitions) system’s total ownership cost over a 30-year service life. O&S costs, as a percentage of life-cycle costs, increase significantly if a system is in service beyond its expected service life—a relatively common occurrence for systems today. The O&S phase typically lasts 30 years or more, with some programs in service for well over 50 years (e.g., B-52s, KC-135s).

Systems typically do not enter the O&S phase in a competitive sourcing environment, although competition has become an increasingly common practice through the use of competitive performance-based logistics contracts. This subsection describes the elements that make up O&S costs, the DoD’s O&S expenditures over time, and the DoD’s efforts to curtail O&S costs.

O&S Elements

According to the DoD’s Division of Program Analysis and Evaluation, O&S refers to “all personnel, equipment, supplies, software, services, including contract support, associated with operating, modifying, maintaining, supplying, training, and supporting a defense acquisition

program in the DoD inventory. This includes costs directly and indirectly attributable to the specific defense program; i.e., costs that would not occur if the program did not exist” (Chu, 1992). For administrative purposes, O&S costs are categorized into six primary groups. These categories are labeled unit-level manpower, unit operations, maintenance, sustaining support, continuing system improvements, and indirect support.

Unit-Level Manpower

The unit-level manpower category records costs associated with the manpower needed to operate unit-level operational entities. Here, *unit-level* refers to the military or civilian organizational unit responsible for using the defense system. For example, costs are included for all user/operator, maintenance and other support manpower that accrue, regardless of whether the personnel are military, civilian, or contractor. The purpose of this grouping is to capture the direct costs of operating unit-level entities (Cost Analysis Improvement Group, 2007).

Unit Operations

Unit operations accounts for all costs associated with unit-level consumption of operating materials. This category includes costs for energy requirements, expendable stores, and other operational materials. The cost for this group has historically been highly volatile, primarily due to fluctuations in energy prices.

Maintenance

Maintenance includes the cost of labor for maintenance tasks, as well as the cost of materials “at all levels of maintenance in support of the primary system, simulators, training devices and associated support equipment” (Cost Analysis Improvement Group, 2007). Specifically, this category includes all costs associated with organizational maintenance and support—including organization-level and intermediate consumables, organization-level and intermediate repair parts, organization-level and intermediate reparable parts, depot maintenance, and any associated labor costs for these specific tasks.

Sustaining Support

Sustaining support refers to the sustaining costs that can be identified as unique to that specific system. This excludes all support activities that are conducted by the units that operate the systems. Unique system costs include system-specific training for operators and non-operators, support equipment replacement, sustaining engineering and program management, as well as other associated sustaining support requirements such as test and evaluation in support of deployed systems and communication services.

Continuing System Improvements

This category captures costs that occur due to updates or upgrades after the system is deployed. Updates can be allocated either to hardware modifications or modernization, or to software maintenance and modifications. This calculation does not include the costs of improvements that are part of an incremental evolutionary acquisition strategy or pre-planned improvement program. (These are covered under the R&D and production phases of the program.)

Indirect Support

As its label implies, the indirect support group records the costs incurred by facilities and personnel that cannot be directly attributed to a system. For example, a new system requires numerous changes in the military to accommodate its existence, including possible expansion of current base facilities to house the system and its required personnel. Indirect support costs can be attributed to installation support, personnel support, or general education and training not associated with a specific system. Indirect support costs are typically not constant throughout a system's lifespan.

Growing O&S Expenditures

O&S costs have represented a significant expenditure for the DoD throughout its history. Initially, O&S costs were marginal because the technical complexity and average age of systems was relatively low. Over time, however, O&S costs have grown significantly. Between FY1948 and FY1999, the DoD expended an average of 17% of its budget on O&S. Between FY1999 and FY2009, however, the DoD expended an average of 29% of its budget on O&S costs. By FY

2009, it had reached 40%. When considering operations and maintenance (O&M) costs, which includes both O&S costs and labor pay, the DoD's expenditures averaged 32% since the DoD's inception and 40% this past decade (Department of Defense [DoD], 2008). Figure 4 shows O&S and O&M costs as a percentage of the total DoD outlays between FY1960 and FY2009.

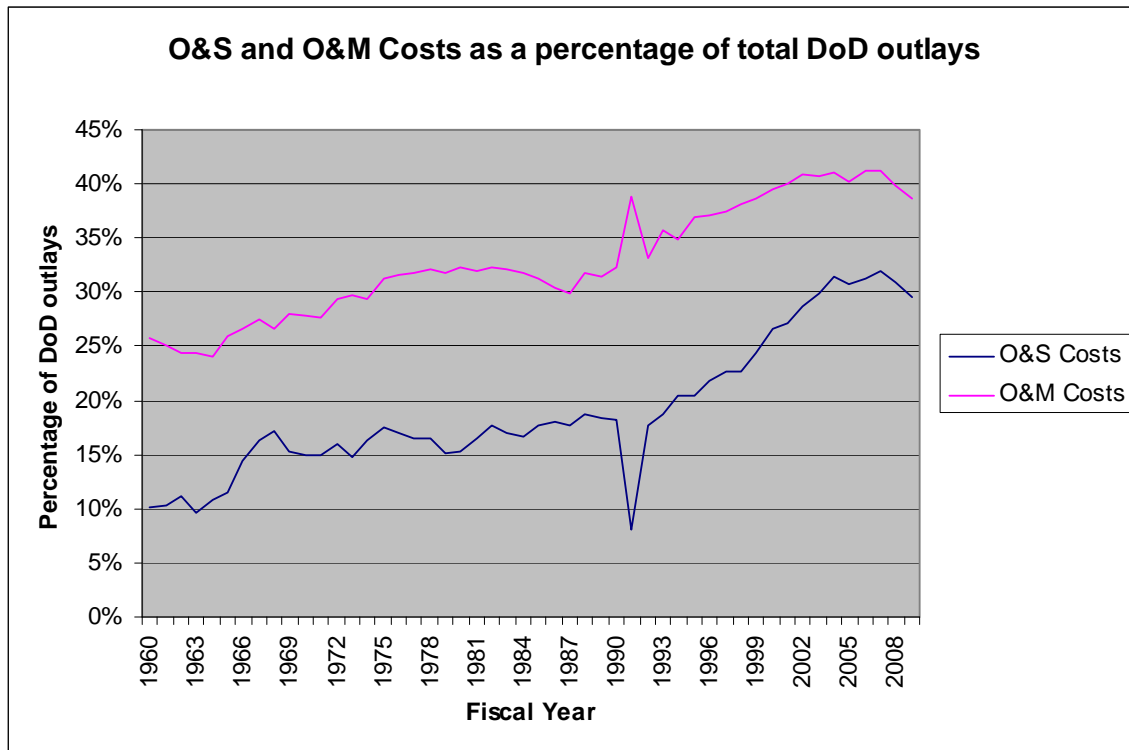


Figure 4: O&S and O&M Costs as a Percentage of Total DoD Outlays
Source: (DoD, 2008)¹

Reported O&S Costs Underestimate True Support Costs

Most defense procurement contracts are written so that contractors are required to support systems for a number of years after they have been delivered to the DoD (Devers & Salerno,

¹ An abnormality occurs for data from FY1991, the fiscal year in which the Persian Gulf War took place. In the DoD's Green Book, O&M costs increased marginally from \$158 billion in FY1990 to \$166 billion in FY1991, but O&S costs decreased from \$89 billion to \$34 billion. This decrease is almost completely accounted for by the contribution of coalition countries of almost \$54 billion to offset the U.S.'s incremental costs for the war. The spikes in the graphs are a result of the following: (a) the DoD's overall outlays decreased 13% due to the contribution of coalition countries, creating a lower base value that caused marginal changes to appear to be more significant in the relative context; (b) coalition contributions directly decreased O&S costs while other expenditures remained relatively constant, causing O&S costs to spike downward; and (c) the O&M outlays number includes O&S outlays before the coalition contributions reduced that burden, making it appear that O&M costs spiked upward when they only increased marginally (5%) from the previous year and fell moderately (10%) the year after.

1993; Stouffer, 2008). In this way, these support costs are typically counted as procurement costs when they should be counted as O&S costs. As a result, O&S costs tend to be underestimated.

O&S Costs Projected to Rise in the Future

Several organizations, including the GAO, project continued O&S cost increases in the near future. Costs in the short-term will rise due to increased operational activities, primarily attributable to the conflicts in Iraq and Afghanistan. Over the longer term, other factors will contribute to costs, including “aging military infrastructure and equipment; increased costs for installation security, antiterrorism force protection, communications, information technology, transportation, fuel, and utilities,” as well as the increased technical complexity of systems that will be updated more often than systems were in the past (Lepore, 2007).

O&S costs have increased at a faster rate than the DoD’s budget, which has experienced over 2% real growth. Given the size and importance of these costs, continued growth may limit the DoD’s ability to achieve its modernization objectives.

The DoD’s Efforts to Curtail O&S Costs

The DoD has undertaken several efforts to curtail O&S cost growth, including implementation of use of performance-based logistics and new sustainment metrics.

Performance-Based Logistics

The DoD’s performance in logistics has been subpar compared to its commercial-sector counterparts. Much of the DoD’s inefficiencies stem from its historic governance as a “just-in-case” logistics system in which performance was based on ensuring that sufficient stockpiles of supplies existed in case the military suddenly became involved in a protracted conflict.

Although the just-in-case system minimizes the likelihood the military will run out of supplies, it is not a cost-effective solution. The logistics situation was made worse as the just-in-case system spawned a significant “supply-push” problem. Major defense contractors were typically given sole-source contracts to support systems they had developed, and these firms made significant profits selling spare parts. As a result, firms had few incentives to design a system around

affordability or reliability constraints. In an effort to reverse these trends, the DoD has embraced the use of performance-based logistics (PBL) to improve logistics performance and reduce O&S costs.²

PBL shifts the focus of the government's efforts from transactions (buying spare parts) to identifying performance outcomes and assigning responsibilities. With PBL, active management of the sustainment process (e.g., forecasting demand, maintaining inventory, and scheduling repairs) becomes the responsibility of the support provider. Most important, PBL changes the incentives for the contractor. With a properly structured PBL program, the contractor is incentivized to improve the reliability of systems and, as a result, to reduce the need for repairs and spare parts. Since the contractor makes fewer repairs, the contractor stands to make more profit (since the cost of repairs was priced into his bid). From the government's perspective, PBL results in optimizing total system availability and, at the same time, minimizing cost and logistics footprints. When implemented in a competitive environment, PBL enables the DoD to achieve increased performance at lower costs; in practice, PBL has typically delivered these results.

Sustainment Metrics

The Office of the Secretary of Defense has also defined “three mandatory sustainment requirements to ensure that effective sustainment is addressed and accomplished over the life cycle for all newly developed and fielded systems” (Office of the Secretary of Defense, 2009). The three requirements include one Key Performance Parameter (KPP), availability, and two Key System Attributes (KSA), reliability and ownership cost. The purpose of the availability metric is to determine fleet readiness and operational availability. The reliability metric is used to determine how likely a system is to perform its mission, given specific environmental or wartime conditions, while the ownership cost metric provides a fuller picture of the life-cycle

² DoD 5000.1, in Enclosure E1.1.17, directs that, “PMs [Program Managers] shall develop and implement performance-based logistics strategies that optimize total system availability while minimizing cost and logistics footprint. Trade-off decisions involving cost, useful service, and effectiveness shall consider corrosion prevention and mitigation. Sustainment strategies shall include the best use of public and private sector capabilities through government/industry partnering initiatives, in accordance with statutory requirements.”

costs of a system. The explicit goal of the DoD is to “balance the sustainment metrics” (Office of the Secretary of Defense, 2009). The Chairman of the Joint Chiefs of Staff first defined these requirements in 2006 (Nolte & Quackenbush, 2008). Implementation of these sustainment metrics reflects the DoD’s commitment to reduce O&S costs and pursue fiscally sustainable military systems.

Of these new metrics, ownership cost is perhaps the most important. Ownership cost helps prioritize energy efficiency in an acquisition environment in which performance capabilities or mission requirements often trump financial considerations.

Contractor Decisions and O&S Cost Determination

Decisions made by contractors early in the design process influence O&S costs to different degrees. Figure 5 presents the RAND Corporation’s determination of the “extent of contractor influence on the major categories of O&S cost in a typical fighter aircraft program” (Birkler & Graser, 2001). It can be argued that many of these determinations are applicable to other DoD acquisition programs, especially those systems with high O&S costs. The life-cycle costs of missiles, ammunition, and other acquisitions with low O&S costs are also affected by contractor decisions, but potential savings from those programs would stem from reduced R&D and production costs.

After examining Figure 5, it is clear that contractor decisions have an important impact on life-cycle costs. If neither the DoD nor contractors properly account for life-cycle costs during development, the DoD could incur much higher system costs than would have been required with such forethought. The DoD’s obligation to consider life-cycle costs was recently strengthened by Congress in the Weapons Systems Acquisition Reform Act (WSARA) of 2009.

Degree of Contractor Influence over O&S Costs

O&S Cost Category	Contractor Influence		
	High	Medium	Low
Mission Personnel			
Officers			X
Enlisted		X	
Civilians		X	
Unit-level Consumption			
Petroleum, oil, and lubricants		X	
Consumable supplies	X		
Depot-level reparable	X		
Training munitions			X
Intermediate Maintenance			
Officers			X
Enlisted		X	
Civilian		X	
Contractor		X	
Consumable material/repair parts		X	
Depot Maintenance			
Aircraft overhaul			
Airframe	X		
Engine	X		
Support equipment repair	X		
Sustaining Support			
Support equipment replacement		X	
Modifications		X	
Sustaining engineering services		X	
Software maintenance		X	
Simulator operations			X
Technical publications			X
Indirect Support			
Specialty training			X
Permanent change of station			X
Military medical care			X
Installation support			X

Figure 5: Degree of Contractor Influence Over O&S Costs

Source: (Birkler & Graser, 2001)

III. Competition and the Defense Market

Competition is the driving force in the U.S. economy. Competition has been proven to encourage organizations to improve quality, innovate for improved performance, reduce costs, make product design and process improvements, and focus on being more responsive to changing customer needs. Competition offers these same advantages to defense acquisitions because a firm receiving a single-source contract lacks competition; such monopolistic firms tend to maximize profits by raising costs and continuing to produce the same goods and services as they have in the past.

Competition

In economics, competition can be defined in a number of different ways. For the purposes of this paper, competition is the effort of two or more parties, acting independently, to secure the business of a third party by offering the most favorable terms (Gansler & Lucyshyn, 2008). Advantages include economic efficiency, increased innovation, improved quality, and increased performance. Numerous entities, both public and private, have asserted that the DoD can capture many of these same benefits if it “substantially increased use of commercial-style competition, emphasizing quality and established performance as well as price” when awarding contracts (Packard Commission, 1986).

Economic Efficiency

Economic efficiency is the outcome of competitive markets. Economic efficiency is the outcome in which the cost of producing a given output, given a level of quality, is as low as possible. In other words, the specific item or service could not be provided with fewer resources. Given competitive forces, each firm has an incentive to achieve efficiency.

Competition provides firms both a positive and a negative incentive—the carrot and the stick—by rewarding competitive firms with higher profits, and a larger market share, while punishing non-competitive firms through reduced profitability, declines in market share, and eventually withdrawal from the market.

Contrary to the commercial sector, where the quantity of goods sold increases significantly as the price falls (price elasticity), the quantities bought in the defense sector are usually determined by the existing force structure as well as by budget constraints. Contractors may strive to win future contracts through good performance, but the government's demand for defense systems is highly inelastic to price. Thus, contractors cannot increase market share of the defense industry as quickly or as effectively as competitive firms in the private sector. Under the DoD's sole-source, fixed-quantity conditions, firms have few incentives to find ways to reduce costs.

Innovation

Competition creates pressure for firms to differentiate themselves from rival firms to win business. In order to acquire a comparative advantage in providing a particular service, a firm must be innovative in its business model in order to realize gains in efficiency or quality through methods the rival firms have not implemented. Innovation is possible in every aspect of a business; firms can realize gains in productivity through new manufacturing techniques just as they could by recruiting more experienced employees. In the defense industry, like many high-tech industries, technological innovation is an essential ingredient of market success. Making new scientific and technological discoveries is important to being competitive in the defense industry, but there are a number of factors that limit competition and the incentives for innovation. The characteristics of the invention, the strength of intellectual property protection, the extent of competition before and after innovation, barriers to entry in production and R&D, and the dynamics of R&D all influence firms' incentives and willingness to compete and innovate (Gansler & Lucyshyn, 2008).

Quality

An additional benefit of competition is the improvement in product quality. High quality requires both that products have a low probability of being defective and that products have high durability. This concern is of particular importance for the military because weapon systems are often exposed to frequent use, irregular maintenance, extreme weather, and intense battlefield conditions; the durability and reliability of weapons systems may be all that separates success and defeat in combat. The military takes quality very seriously, as is reflected in its lengthy lists

of requirements for weapons systems. In some fixed-price contracts with warranties, the firm is responsible for the cost of replacing faulty parts in its products. Because the DoD values quality due to its unique requirements, quality is often one of the most important factors a developer must incorporate into its product's design.

Performance Improvements

The U.S. military's preeminence in global security owes much to its willingness to invest in new technologies that give it a qualitative edge in capabilities over potential adversaries.

Performance improvements—any modification that improves a product's capabilities—are another benefit of competitive pressure. When firms compete for the opportunity to build systems, performance is a tangible factor that allows one firm's product to be deemed superior to a competitor's product. Performance improvements are particularly attractive when acquisitions strategies use “best-value” criteria for source selection, allowing the buyer to weigh the benefits of additional performance with change in cost. Moreover, as with quality, competition provides incentives for continuous improvement that ultimately results in higher performance at lower costs.

Market Structures

The structure of a market is important to determine if competition exists and, if so, how effective it might be.

In this section we first compare the defense market structure with an idealized, perfectly competitive market structure to highlight their differences. Then, we make a comparison between the environments of a contract in the production phase and a typical monopoly structure in order to highlight the similarities between the latter pair.

Perfectly Competitive Market vs. Defense Contracting Market

Perfectly competitive markets do not exist in the real world, but they represent a model of economic efficiency that many markets resemble (especially those with many buyers and many sellers). Perfectly competitive markets have several unique qualities that differ substantially

from the defense contracting market. These differences are listed in Figure 6. The first unique quality of perfectly competitive markets is that a large number of competing buyers and sellers exist in the market. As a result, no single buyer or seller is able to influence market prices. Second, buyers and sellers have perfect information, and, as a result, no one entity is able to gain an advantage over the rest through superior knowledge. Third, the goods or services sold in the market are homogenous and are perfectly substitutable. Fourth, firms may buy and sell goods with negligible transaction fees, meaning that purchases occur quickly and without lengthy negotiation. Firms do not worry about regulations or laws, and do not waste resources dealing with the government or protesting the awarding of contracts to a competitor. Finally, firms have freedom of entry and exit to and from the market, as low barriers to market entry and exit exist. In this model, competition naturally produces an optimal market allocation of supply and demand in which no one has market share or the power to influence the price or quantity of a good sold. In other words, the structure of a “perfectly competitive market” produces “perfect economic efficiency.”

The defense market differs significantly from the perfectly competitive market ideal. Understanding the differences between the unique structure of the defense market and the perfectly competitive market is important to developing defense acquisition policies that increase competition and reduce market collusion (whereby competitors attempt to coordinate their bids to maximize profits).

The defense market has several defining features, which differ from a perfectly competitive market. First and foremost, the defense market has essentially a single buyer, the DoD (single-buyer markets are also referred to as monopsonist). When a single-source contract is awarded by the government, the defense market’s only customer, there is a market with one buyer and one seller, a bilateral monopoly. Since many defense systems are sufficiently unique, contractors have the bargaining power of a monopolist. The government, as sole buyer, always has the option of not purchasing services it does not desire. This market is quite unique when compared to a perfectly competitive market, as there are no market mechanisms to determine price and quantity. In a bilateral monopoly, there are three possible outcomes: 1) one party dominates and forces the other to accept price and quantity, 2) both parties reach an agreement through bargaining, or 3) the market mechanism breaks down (Beltramo, 1983). To say that the market

mechanism breaks down is to say that negotiations break down. “A contract substitutes an administrative mechanism for a market mechanism and a fee in lieu of profits forgone” (Beltramo, 1983).

In addition to being the sole buyer, the government is also the sole market regulator, which complicates the federal government’s role considerably. Although most monopsonists are able to use their market leverage to reduce costs, the federal government is often unable to exert this influence. One reason for this is that the non-DoD portion of the federal government, as market regulator, has numerous political considerations that take precedence over economic efficiency. For example, congressional pressure may favor a specific program because it may benefit firms in key congressional districts, regardless of the DoD system’s actual requirements. Also, regulations that encourage the government to award contracts that further socioeconomic and political causes may result in suboptimal contracting outcomes. Another complicating factor is that the defense market is made-up of only a few large firms capable of producing major weapon systems, which limits competition.

Unlike a perfectly competitive market, there are high barriers to entry in the defense market. In order to enter the market, a firm needs high technological capabilities, sophisticated legal and political understanding, and sufficient financial resources. With the government as a firm’s principal customer, the firm must be large and diverse enough to engage in multiple projects simultaneously. Otherwise, a firm may be forced to slash its workforce if it experiences a significant gap between contracts. Fourth, given the cutting-edge research and development conducted by the firms in this market, perfect information does not exist. As a result, it is difficult for market participants to determine the correct market price, especially when it is unknown how much research will be required to achieve a desired capability. Fourth, many products in the defense acquisition market are unique. Defense systems are tailor-made to suit the unique needs of the DoD, which generally prioritizes performance, durability, and reliability over cost. Differentiation between products limits competition because the seller, once selected, can act as a monopoly seller. For cases in which a single firm has performed the advanced research and constructed a prototype, it may be difficult for a second firm to compete without the opportunity to purchase or receive technology from the first contractor. Finally, the defense market has high transaction costs. Compliance with federal acquisition regulation is costly and

time-consuming (Gansler, 1989). Finally, many larger contracts are protested, causing further costs and delays.

Perfectly Competitive Market	Defense Market
Many buyers, none of whom can influence the market price	One buyer (the federal government)
Many sellers, none of whom can influence the market price	A few large defense firms
Sellers focus on winning each award	Frequent use of teaming
No barriers to entry or exit	High technological, legal, political, and fiscal barriers to entry
Perfect information	For most items, limited information due to cutting edge research and development
Homogenous products	Most items are highly differentiated
No or low transaction costs	High transaction costs

Figure 6: Perfectly Competitive Market and Defense Market Structures

Source: (Katz & Rosen, 1998)

Monopoly Structure vs. Defense Contract Competition in the Production Phase

As noted previously, the DoD tends to buy highly differentiable products. Especially for instances in which the DoD is acquiring a new system, its selection of a design for the final product essentially grants the winning firm a monopoly. Significantly, programs typically move from a competitive environment to a sole-source environment once a program enters the production phase.

Three similarities exist between an ideal monopoly structure and the environment of a system that enters the production phase. First, in both instances (particularly assuming the product or service is required), a single seller can influence the price of the product. Even if the seller in the defense industry has a commitment to sell at a given price, with a fixed-price contract, the costs of a program usually change significantly between initial estimates and production; these are often based on “required” customer changes, increasing the overall price (Rogerson, 1994). Second, a monopoly enjoys its position because of high barriers to entry. Once the DoD has selected a single firm to proceed with development, there are high barriers for other firms to join the competition. Unless the DoD is so unimpressed by the contractor’s performance that it opens up competition to a second firm, it is unlikely that a firm will be given the opportunity to compete for the contract. Finally, a monopoly is able to maintain its status in large part because

it produces a unique product. Each of the DoD’s MDAPs is a unique system that has few, if any, close substitutes. If the firm is not required to share its technical data, then there is a substantial technological barrier to entry for other firms to compete in producing related goods. Once the DoD has committed to only one firm, it must return to that single source for its products and supplies. The similarities between these two environments are highlighted in Figure 7.

Monopoly	Defense project after selecting a firm
Single seller that can influence the price	Single seller that can influence the price
Many buyers that are price takers	Single buyer that has some, though less, influence over price
High barriers to entry	High barriers to entry
Unique product	Unique product

Figure 7: Monopoly Market and Typical Program Market Structures
 Source: (Katz & Rosen, 1998)

Although the purpose of a contract is to set firm obligations between buyer and seller, many of the DoD’s contracts undermine the government’s bargaining position by excluding other firms from competing. The DoD often enters into sole-source contracts, sometimes even before completion of the development phase of a project, despite evidence that competition can provide significant benefits. Consequently, the government’s commitment to buy from one firm creates an environment in which the winning firm has few incentives to continue to deliver results beyond the absolute required minimum and at increasing prices (as changes come along).

A defense firm’s monopoly often extends into the Operations and Support (O&S) phase as well. If the original producer of a system expects to obtain a sole-source contract for support functions for the first few years (at least) of O&S, then the firm has little incentive to research ways to decrease its product’s O&S costs while in the development or production stage. In fact, unless properly structured, the firm may increase its profits if the system requires more repairs and spares. As a result, these types of contracts can benefit the receiving firm, but only at the expense of the government, which generally receives a defense system with higher life-cycle costs, lower quality, and decreased performance.

Competition During Production: Competitive Dual-Sourcing

Theoretically, a single producer should be able to capture all the benefits of the learning curve,³ delivering the lowest cost for the product available to the consumer. Learning curve theory does not suggest that all firms are equal, but rather that each firm, with its unique comparative advantages and disadvantages, possesses a unique curve. The most competitive firm would generally have a curve that is below its rivals, as it produces goods more efficiently than its rivals, at a given level of output.

For an organization seeking contractors to provide a service, in this case the DoD, their task is to choose the most competitive firm. Based on this theory, the DoD would appear to have little reason to consider establishing a second source. If the contract is awarded to the most competitive firm, then it should realize the largest gains in efficiency as production expands and the selected contractor is able to produce a more competitively priced good than its competitors.

However, learning-curve theory is based on a continuously competitive market, which causes the firms to move down the learning curves.

The DoD's experience with sole-source contracts suggests otherwise. Learning curve theory is predicated on incentives to achieve productivity improvement (i.e., the learning curve's downward slope reflects the decisions of firms to innovate and improve on their techniques to achieve a more efficient rate of production). Absent competition, there is little or no incentive for firms to innovate or improve. And, as a result, single-source defense contracts, which by definition exclude competition, fail to achieve the same potential gains.

For major defense acquisitions, a sole-source provider can maintain a monopoly in the market for its product for 20 years or more. After receiving the contract, the contractor has every reason to celebrate and no incentive to innovate. As a result, observed learning curves "are generally

³ The learning curve is the primary theoretical framework for the comparison of production that occurs in sole-source and competitive environments. Sometimes referred to as the "experience," "progress," or "improvement" curves, the learning curve is a graphical representation of how firms "learn" how to produce goods more efficiently as they increase production. The curve shows that firms spend more money and time (Y axis) on creating each individual unit (Quantity measured on X axis) when beginning production. Efficiency gains are rapid in the beginning as firms become more proficient, but gradually assume a slightly downward slope (in the long run, technological advances afford additional, marginal increases in productivity).

flatter than projected” (Gansler & Lucyshyn, 2008). In some instances, learning curves have even risen—particularly if the military has added program requirements that have forced changes to the system’s design.

Critics of competitive dual-sourcing might respond by citing more microeconomic theory. This theory suggests that markets with two principal producers of a good (duopoly) may work together (i.e., collude) to maximize profits at the expense of consumers. According to these critics, competitive dual-sourcing may produce negligible incentives for companies to innovate, while incurring additional costs for maintaining a second line of production and reducing efficiency through smaller economies of scale. This argument will receive closer examination in a later section; however, there is no evidence for such collusion in defense procurements (for a variety of reasons, as discussed later).

In most private markets, even if a single firm is selected to provide a product, the threat of competition is enough to produce the beneficial effects of competition because (a) close substitutes to the product exist, (b) the seller must satisfy more than one buyer, and (c) the seller usually has a relatively limited contract (in terms of time) with the buyer.

Figure 8 illustrates a generalized version, based on historical data, of what occurs in most programs in which the DoD has introduced competition during the production phase. While the first source has a comparative advantage in producing this good (as evidenced by its much lower unit cost prior to the introduction of competition), it does not put forth its best effort until a second source is introduced and both are equally efficient at producing the good. From that point forward, both the first source and second source follow a steeper learning curve than the first source would have followed in a sole-source environment. Competition ensures that firms will continue to move down the learning curve toward lower prices while retaining or improving the overall quality of the product.

The Impact of Production Phase Competition

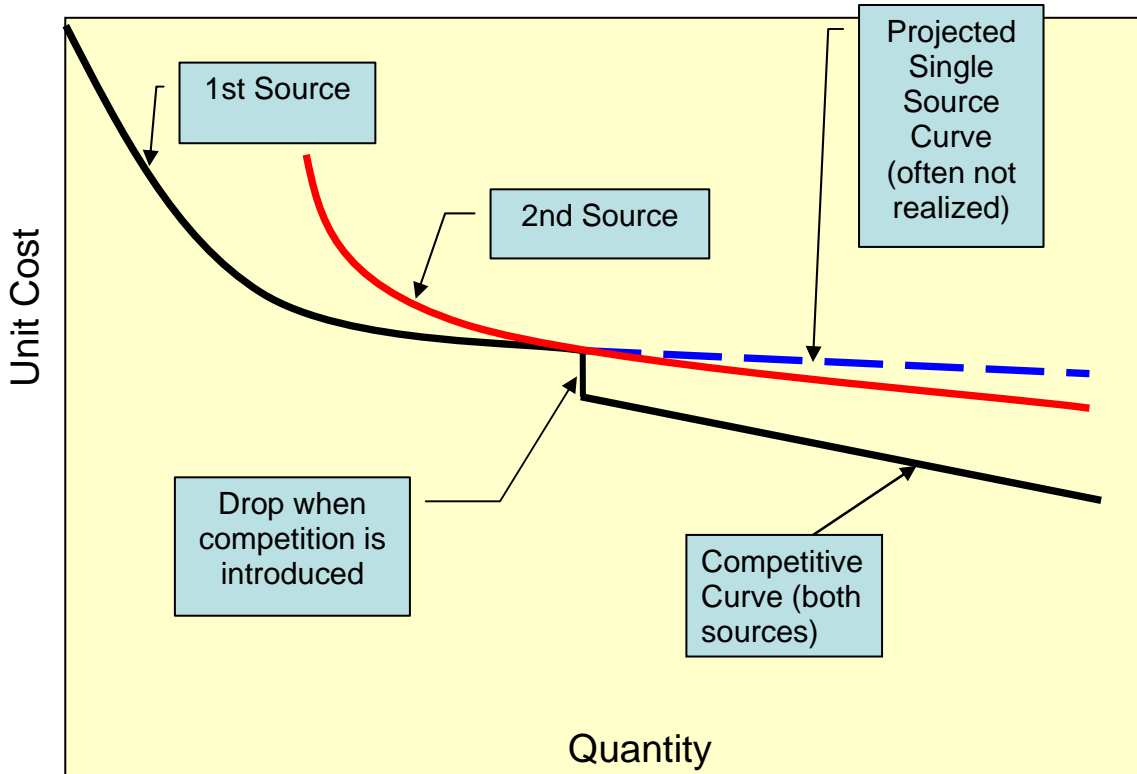


Figure 8: The Impact of Production Phase Competition
Source: (Gansler, 2007)

While learning curve theory suggests that the original producer (which presumably had a comparative advantage in producing this good) should win all of the re-competed contracts, the second source won the competition for full production in most cases (Defense Science Board, 1996). For example, the Defense Science Board found that continuous competition during production for U.S. tactical missile programs resulted in steeper learning curves for both producers, ranging from 2% to 9% (Defense Science Board, 1996).

Although competition during production has been shown to have steepened the learning curve and lowered unit costs, this competition will not result in a net production cost reduction unless the savings from competition outweigh the initial and recurring costs required to operate the second production line. The costs of maintaining a second production line will be addressed and enumerated in the case studies discussed later.

One way of examining these gains in efficiency is by measuring the program net-cost growth. The aircraft produced in the competitive private-sector environment (see Figure 9) achieved cost savings that ranged from 2% to 27%, with an average savings rate of 16% (Aircraft Value Analysis Company, 2006). Several of these aircraft are substitutable, and all were developed by and produced in a competitive environment for private firms, not the government.

Aircraft	Net Cost Growth
B737-400	0.76
B757-200ER	0.80
A310-300	0.98
A320	0.92
A330-300	0.86
DC10-30	0.83
MD-11	0.73
Average	0.84

Figure 9: Summary of Commercial Aircraft Produced in a Competitive Environment
Source: (Aircraft Value Analysis Company, 2006)

In contrast, a RAND analysis of cost growth in military jets in which competition for production did not exist found very different results. The difference between initial program baselines and actual costs amounted to an average cost growth of 46%, ranging from 4% cost reduction to 104% cost growth. Figure 10 displays the findings from the military aircraft report. These comparisons of competitively awarded contracts between private firms and DoD single-source contracts clearly demonstrate the value and potential savings from a competitive environment during production.

Aircraft	Net Cost Growth
A-6E/F	0.96
B-1B	0.98
C-17	1.70
EF-111A	1.62
F/A-18 A-D	1.54
F-14A	1.25
F-15A-D	1.47
F-16A-D	1.29
JSTARS	2.04
T-45	1.74
Average	1.459

Figure 10: Cost Growth Factors for the DoD Aircraft Programs With No Production Competition
Source: (Birkler & Graser, 2001)

There are two complementary explanations for the discrepancy between these firms' cost growth factors. First, firms were more efficient and realized cost savings in the private sector because they had an incentive to do so. Firms had an incentive to innovate as the firm's cost savings increased its sales and profitability, giving successful firms a comparative advantage over rival firms with comparable products. Firms that received a sole-source contract from the government, however, had no such incentive because they faced no competition. The second driver for cost growth was poor cost estimation. Firms developing products for private-sector companies had more realistic cost estimates, perhaps because firms' profitability hinges on the small difference between cost and revenue. The DoD's cost estimates, on the other hand, tend to underestimate a program's total cost.

Another way to interpret the cost-growth table in Figure 10 is to emphasize the DoD's unique technological requirements; DoD aircraft implement highly advanced technologies that are not commercially available and require more R&D investment than commercial aircraft. While cost growth does occur in the research and development stages of the acquisition process, it can only account for a small percentage of all of the cost growth shown in Figure 10. Cost growth is more frequent in the production and O&S phases of the acquisitions process, which account for almost 90% of life-cycle cost (the total cost of a defense system from concept to disposal; GAO, 2003). Sustained and widespread cost growth of defense contracts in the public sector suggests that contractors in non-competitive defense markets operate less efficiently than firms in the competitive private sector.

Weapon Systems Acquisition Reform Act of 2009

Congress signed the Weapons Systems Acquisition Reform Act of 2009 into law in May 2009. This act attempts to address some of the shortcomings of the current acquisition system, where short-term objectives typically outweigh long-term concerns. The act addresses these concerns by emphasizing (a) consideration of life-cycle costs (and, in doing so, O&M costs) and (b) use of effective competition throughout the life cycle, whenever it is cost effective to do so. These policies build on established DoD policies that have been shown to increase competition and reduce LCC costs, such as use of commercial-off-the-shelf (COTS) technologies and commercial standards. If all of these policies are fully implemented, the DoD would significantly improve its acquisition outcomes.

The act calls for “measures to ensure competition, or the option of competition, at both the prime contract level and the subcontract level (at such tier or tiers as are appropriate) of such program throughout the life-cycle of such program as a means to improve contractor performance” (WSARA, 2009). Measures include consideration of life-cycle costs when making programmatic decisions, greater use of independent cost estimates, and the establishment of new senior-level positions to manage the acquisition process. This statute was implemented too recently to evaluate its impact on the defense acquisition process.

IV. Examining O&S Costs for Competitive Dual-Sourcing Cases

The number of cases of competition during production, or competitive dual-sourcing, is limited for a number of reasons. First, competitive dual-sourcing has certainly not been the DoD's normal approach to systems acquisitions. Recently, the DoD has been reluctant to assume the costs of maintaining a second production line, based on the assumption that this would increase program costs. Second, the majority of programs that experience competition during the production phase do not lend themselves well to an analysis of the benefits of production competition on O&S costs. Programs that do experience competition during the production phase are likely to be (a) systems that are build-to-print and will have minimal O&S cost differences, or (b) munitions, which typically have small O&S costs. Finally, comparisons are also difficult due to the limited amount of data that is publicly available on program cost and reliability.

Previous experience in introducing competitive dual-sourcing during production suggests that significant cost savings are possible during the production stage alone—without even addressing life-cycle benefits. In the cases analyzed in this section, the savings and performance improvements achieved under competitive dual-sourcing were generally large enough to compensate for the cost increases that resulted from the second line of production.

Competitively dual-sourced defense systems were more reliable, had longer life spans, and needed maintenance or to be replaced less frequently than defense systems that were single-sourced. The data show that expanded competitive dual-sourcing has the potential to reduce O&S costs and help restore fiscal sustainability for the DoD.

Savings From Competitive Dual-Source Production

The savings achieved from competitive dual-sourcing during production from several studies are presented in Figure 11. These studies examined the observed net savings for “recompeted” programs, programs that previously experienced no competition in the production phase.

Initially, most of these programs were awarded as sole-source production contracts, but the DoD grew dissatisfied with the contractors over quality concerns and later solicited a second-source contractor. These studies found that the introduction of competition led to system net savings ranging from 12% to 52%. Also, performance and quality concerns were addressed by both

contractors, such that both contractors produced systems that were of higher quality than what the single-source contractor had pre-competition. Moreover, the studies found that the second source typically won a significant share of the competition—a result that runs counter to the prediction of the learning curve theory. Overall, these results suggest that quality, in addition to cost, should be an important factor in the DoD’s willingness to allow competitive dual-sourcing.

Study Organization	Year	Number of Systems	Observed Net Savings
Scherer	1964	--	25%
McNamara	1965	--	25%
Rand	1968	--	25%
BMI	1969	20	32%
Army Electronics Command	1972	17	50%
LMI	1973	--	15-50%
Joint Economic Committee	1973	20	52%
IDA	1974	20	37%
LMI	1974	1	22%
ARINC	1976	13	47%
APRO	1978	11	12%
IDA	1979	31	31%
TASC	1979	45	30%

Figure 11: Savings Achieved From Competition During Production
Source: (Defense Science Board, 1996)

In these studies, the net savings from the production phase equaled or exceeded the costs of maintaining a second line of production.

Unfortunately, there are only a limited number of cases that have been analyzed to show how competition in the production phase impacts O&S costs. The number of applicable cases is small because (a) the majority of the DoD acquisition programs do not experience competition during the production phase and (b) the vast majority of programs that do experience competition during the production phase are not the types of programs or competitions that allow useful comparisons between O&S outcomes. More specifically, most programs that experience competition during the production phase are (a) a build-to-print competition, (b) involve the production of munitions, or (c) a combination of the first two reasons. When competing

production for a build-to-print system, the government ensures the second-source supplier is provided the technical data needed for production. Because both firms are producing the same items using identical data, the items produced will have minimal, if any, O&S cost differences. Munitions do not lend themselves well to an O&S analysis because they have very low O&S costs and are expended after use.

The second factor that restricts analysis of the effect of competition during the production phase on life-cycle costs is that significant limitations exist with regard to data. These include a lack of consistent methods of tracking the cost and reliability of a system over time, changes in official definitions that complicate comparisons between programs, and a lack of publicly available information. All of these limitations make an analysis of the effect of competition in the production phase more difficult.

Nonetheless, there have been a few cases in which data do exist. This section analyzes several programs that have experienced competitive dual-sourcing in three subsections: build-to-print competition, major subsystem competition, and full system competition; each of these three categories does have some examples of the O&S benefits.

Build-to-Print Competition

Even though, theoretically, there is little difference in O&S costs between build-to-print items, competition during the production phase can still have benefits on a program as a whole, including the O&S phase. Most notably, competitive dual-sourcing of a build-to-print system, as the Tomahawk Cruise Missile illustrates, can help to improve performance, decrease unit costs, and improve the system reliability (thus lowering O&S costs).

Tomahawk Cruise Missile

The Tomahawk Cruise Missile is a long-range cruise missile that can be launched from ship, submarine, and aircraft and is used by both the Air Force and the Navy. First fielded in 1983, the missile has been used successfully in numerous conflicts since its initial deployment.

The missile's program office is the Joint Cruise Missile Program Office. From program initiation, the program office has "directed extensive use of dual competitive sources for all

major elements of the missiles” (Birkler & Large, 1990). This competition has taken the form of competitive dual-sourcing, wherein both firms produce a system from the same design drawings.

Under the original single-source contract, McDonnell Douglas Corporation (MDC) produced the guidance system while General Dynamics/Convair Division (GD/C) produced the airframe and was responsible for integrating the guidance system and airframe. When the first Tomahawk missiles began to exhibit performance concerns and cost overruns, the program office grew concerned that no single contractor was responsible for the entire Tomahawk system. The program office was also concerned by GD/C’s flat projected cost curve (meaning that it expected no future gains in efficiency throughout the contract). To the program office, this suggested that GD/C was not fully competitive (Birkler & Large, 1990). The office decided it wanted both contractors to produce the entire Tomahawk missile separately, wherein each contractor would be solely responsible for the missiles it produced. An increase in the quantity of Tomahawk missiles demanded made competitive dual-sourcing ideal. In 1982, the office initiated the competitive dual-source procurement strategy between GD/C and MDC. The competition awarded contracts annually based on the All-Up Round (AUR), with each firm guaranteed at least 30% of the buy and with the remaining 40% awarded based on contractor performance.

The main obstacle to competitive dual-sourcing was a mutual lack of technical knowledge. GD/C was experienced at airframe construction, but it lacked experience with manufacturing the Tomahawk’s guidance system. MDC was experienced at guidance systems, but it lacked experience with this system’s airframe construction. Both firms lacked the necessary proprietary rights to build the second firm’s components until the contracting office facilitated the transfer between the two firms (Birkler & Large, 1990).

The Navy denied the Cruise Missile Program Office any additional funds for a competitive dual-sourcing program and encouraged the firms to use their own corporate funds for nonrecurring costs associated with the second source. According to the Navy, the firms spent their own funds more wisely than government outlays, and this practice also obviated Navy officials from analyzing and approving every piece of tooling and test equipment needed for competitive dual-sourcing (Birkler & Large, 1990).

The competition produced significant reliability improvements and cost savings. Reliability, the primary concern of the program office and the impetus for the competition, increased from 80% to 97% (Gansler & Lucyshyn, 2008). At the same time, unit costs dropped from an initial cost of approximately \$2.75 million a unit to about \$0.6 million a unit, as shown in Figure 12. As a result, the program achieved its breakeven point three years after competition began. Overall, the competition between 1982 and 1994 was expected to save the military about \$630 million in FY1982 dollars, or \$1.4 billion in FY2010 dollars (Naval Center of Cost Analysis, 1989).

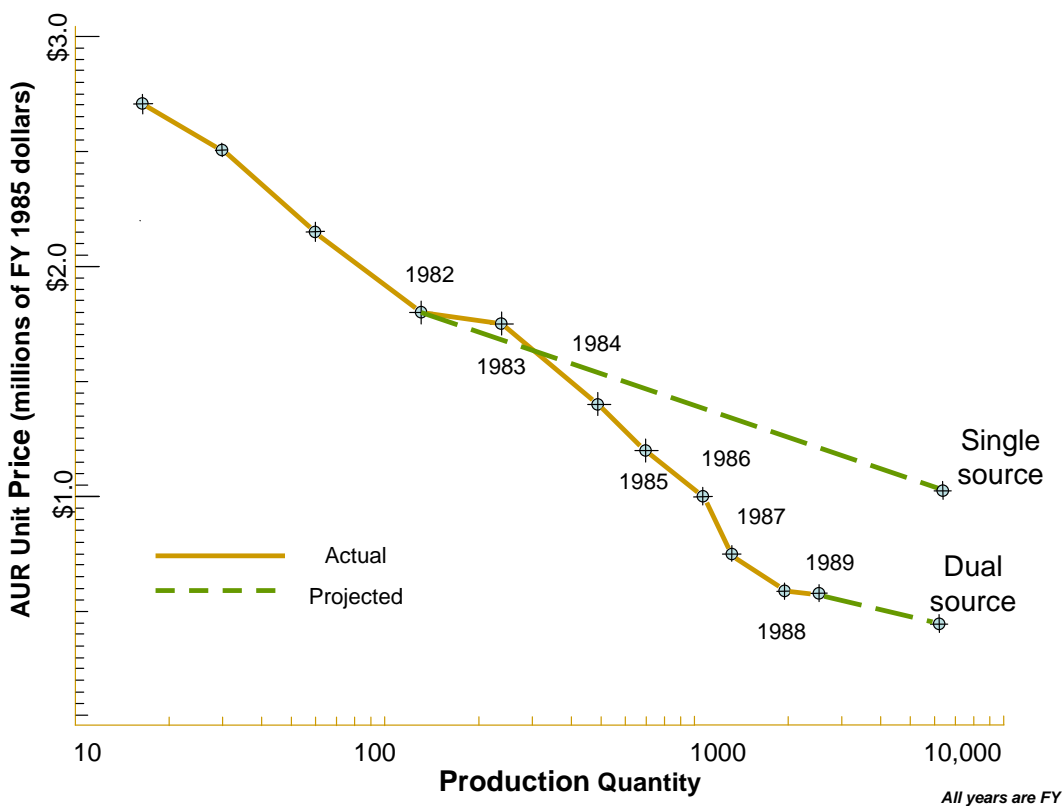


Figure 12: Decrease in Per Unit Production Costs Dual-Sourcing vs. Sole Sourcing
Source: (Birkler & Large, 1990)

Competitive dual-sourcing was a success because the original single-source producer demonstrated its lack of competitiveness and responsiveness to government concerns. Clearly inflated cost estimates for GD/C and the Tomahawk missile's quality concerns alerted the program office to the problem. The government's response was appropriate and effective, as evidenced by the rapid improvements in quality and cost reduction.

Subsystem Competition

Great Engine War

The great engine war was a yearly competition that took place from 1984 to 1994 between the Pratt and Whitney (P&W) F100 engine and the General Electric (GE) F110 engine for service in the then new, single-engine F-16 fighter jet. The P&W F100 was originally designed for the twin-engine F-15 air superiority fighter during the mid-1970s. The Air Force wanted a new engine to power its new fighter, which was designed to have a clear edge over recently developed Soviet MiG fighters. The Air Force required that the engine meet demanding performance requirements, but also be ready for procurement in a short period of time. After an initial design competition, the Air Force selected the P&W design for sole-source development and procurement.

The Alternate Fighter Engine (AFE) program, better known today in systems acquisitions circles as the great engine war, highlights how competition during the production phase of a major subsystem can lead to significant cost savings during the O&S phase. Since an aircraft's engine makes up the greatest portion of an aircraft's O&S and life-cycle costs, reducing engine procurement and sustainment costs would result in significant savings.

F100 Reliability Problems

Although the F100 engine achieved the Air Force's performance requirements, the engine experienced numerous durability and reliability issues that resulted in high O&S cost projections. These reliability issues were due to a number of factors, including the Air Force's hard requirement on a thrust-to-weight ratio of 8:1, a very demanding and untested threshold. Additionally, the powerful engine enabled pilots to use new techniques that increased the stress on the engine. For example, pilots in earlier aircraft typically held the throttle constant once at altitude. In contrast, F-15 pilots changed throttle levels constantly, presenting new and unforeseen fatigue issues for the engine. Of most concern to the Air Force, the rapidly changing throttle levels caused the engine to stall under certain circumstances. Not only could this stall seriously damage the engine but also the only solution to the problem was to shut down the

engine and restart the engine in flight—a condition that was unacceptable in training, let alone in combat conditions. Stall issues led to the loss of several F-15 aircraft.

New engines typically face unexpected performance and reliability issues, particularly if the engine is a new development (like the P&W F100). In most instances, the Air Force primarily funds reliability improvement programs for new engines that it purchases. Although the Air Force provided funds for a reliability improvement program, the Air Force and P&W disagreed over who should pay for the majority of the improvement program's costs, given the significant difficulties the F100 was experiencing (Kennedy, 1985).

As F100 reliability issues persisted, the relationship between the Air Force and P&W deteriorated. By 1979, the Air Force believed that P&W was not putting forth its best effort to improve the reliability of the F100 engine (Kennedy, 1985). Moreover, the Air Force concluded that this situation existed in part because P&W had a sole-source production environment, and so had relatively few incentives to improve reliability (particularly when future cash flow relied upon the sale of a large number of repair parts). The Air Force's concern regarding reliability was heightened as the development of the single-engine F-16 planned to use the F100 engine exclusively. The Air Force feared not only losing F-16 aircraft due to reliability problems but also, given that the P&W F100 would power all frontline fighters, it feared holding little leverage to improve outcomes in the future.

Introduction of Competition

GE, the other major U.S. producer of fighter engines, was effectively closed out of the fighter jet engine market when P&W was awarded winner-take-all (WTA) contracts for the procurement of engines for both the F-15 and F-16. During the 1970s, however, GE had invested its own resources into a replacement engine, known as the F101X, for the Navy's F-14. While the Navy showed little interest in this engine, the Air Force believed that the F101X could be developed into a competitor for the P&W F100 in order to spur competition and reduce operating costs (Camm, 1993).

In 1983, the Air Force reopened competition for F-16 engines by issuing a request for proposal (RFP) for engines for the F-16C/D variants. Both P&W and GE submitted bids for the Alternate

Fighter Engine competition. The Air Force, determined not to be locked into a sole-source production environment again, decided to issue a split-production award that would be re-competed every year. The Air Force's experiment with competitive dual-sourcing would continue until 1994.

The Air Force's decision was met with some skepticism by acquisitions officers who objected to what they perceived to be unnecessary additional costs: higher transaction costs to negotiate two contracts, higher initial production costs, less economies of scale for firms, and higher O&S costs. The last factor was particularly worrisome; the engines were not the same, meaning that the Air Force needed to maintain separate supply chains for both engines.

The Air Force's counterargument was that additional costs (transaction, production, and supply) were outweighed by the possible cost reductions and performance improvements through expanded competition. Moreover, having two engines was also advantageous on national security grounds since serious problems with either engine once in service would only affect a fraction of the military's planes.

Results

The first contract award decision under competitive dual-sourcing was announced in 1984. For FY1984, the DoD awarded GE 75% of the total buy (Kozicharow, 1984). This left the primary, P&W, with a paltry 25%. By rewarding cost-cutting firms, the government improves the responsiveness of individual firms and receives better overall value. Later contract awards seesawed between the two firms, but the government received the most benefits from the great engine war competition.

In addition to rewarding the secondary contractor a majority of the initial lot, the government requested that both firms reevaluate future warranties with an eye toward reducing overall program costs. Congress passed a law in 1983 mandating warranties for all defense systems, but the warranty offered by P&W was so exorbitantly expensive that the House Armed Services Committee decided to buy them uninsured and then insure the engines separately (Hiatt, 1984). It helped that GE offered a very competitive warranty for its engines, which enabled the government to negotiate with P&W for much lower warranties in later years.

Figure 13 highlights the results of the great engine war. The F100 in the first column represents the first engine fielded by P&W, whereas the second and third columns present data on the performance of the GE and P&W engines that the Air Force eventually purchased. Although overall cost savings are unclear due to inconsistent government accounting practices, the GAO estimates that the savings for the first four years of the competition resulted in “total savings of about 21 percent in overall life cycle costs,” when compared to baseline estimates (Sullivan, 2010). In addition to the GAO’s savings analysis, two other studies offered alternative calculations of the total savings: one by the Harvard Kennedy School and the other by RAND. All of these papers reported considerable savings from the competitive dual-source production award (Camm, 1993; Kennedy, 1985; Sullivan, 2010), as discussed later, and the Air Force was quite happy with the results of the competition. According to a *Wall Street Journal* interview with Major Shellnutt, “it has produced offers and concessions from the two bidders that just a few years ago ‘we wouldn’t have dreamed of’” (Seib, 1984).

Characteristic	PW F100(3)	F110-GE-100	F100-PW-220
Operability/Safety			
Stall-stagnations/1000 Flight Hours (FH)	0.2-1	0	0-0.05
Pump reliability Failures/100,000 FH	0.9	0.05-0.1	0.1-0.2
Augmentor operation	R2, R3 instability	No instability	No instability
Supportability			
Cost / FH	\$585	\$215-315	\$285-345
Maintenance Man-Hours (MMH)/FH	8.5	3.3-4.3	4.0-4.6
Removal/1000 FH	7.3	3.0-4.0	3.6-4.4
Life of Hot Section (cycles)	1,800	4,000	4,000
Performance loss	1% / 400 cycles	<2% / 4,000 cycles	<2% / 4,000 cycles

Figure 13: Great Engine War Data

Source: (Camm, 1993)

Estimated Savings in Great Engine War Competition in Billions, FY1983 USD

Year	Savings during Acquisition	Savings during O&S
1985	\$1.40B	\$1.42B
1986	\$1.74B	\$1.51B
1987	\$2.10B	\$1.64B
1988	\$2.13B	\$1.68B
1989	\$2.18B	\$1.71B
Total	\$9.55B	\$7.96B

Figure 14: Estimated Savings in Great Engine War Competition

Source: (Mayes, 1988)

Reduced O&S costs: The cost to maintain and repair engines fell dramatically after competition was introduced. The cost per flight hour for both of the new engines was 50% lower than the P&W F100. The program office estimated that the competition yielded between \$2–3 billion in net savings over the length of the contract (Kennedy, 1985). Mayes (1988), however, provided a more comprehensive estimate for O&S savings of \$7.96 billion (in constant FY1983 dollars), or approximately \$18 billion when adjusted for current FY2010 dollars.

Improved engine reliability: After introduction of competition, engine reliability increased dramatically. For example, the shop-visit rate per 1,000 engine flight hours fell to half of its pre-competition average, while the scheduled depot return rate increased from 900 cycles to 4,000 cycles (Camm, 1993). Most important, the new engines significantly reduced the incidence of stall stagnation while extending the service life of the engine.

Improved performance over time: Engine performance improved throughout the life span of the engines. Although the Air Force contributed money to the improvement programs, the companies contributed significant funds to improve the performance and quality of their engines. As a result, the Air Force was able to acquire better engines over time at a decreasing unit price

and with relatively small contributions to the engine improvement programs (relative to other engine improvement programs).

Improved contractor responsiveness: The main impetus for the great engine war was the Air Force's belief that P&W was not responsive to its concerns. After establishing competition, the contractors consistently addressed the concerns of the Air Force by addressing safety concerns, increasing durability and lowering maintenance costs. Moreover, the continuation of competition enabled the Air Force to receive prompt service at low cost.

Helped to maintain the industrial base: If competition was not established, P&W would have been the sole provider of military jet engines for both of the Air Force's frontline jet fighters for at least a decade. Although GE was a large multinational corporation that had extensive presence in the commercial jet engine market, it is unclear if GE would have maintained its military jet engine division without the prospect of a new full-time production engine in the near future—especially since P&W was awarded the contract to develop the engine for the next generation of fighter aircraft (today known as the F-22). If GE had not benefitted from the decision to offer a competitive dual-source contract, P&W would potentially have had a monopoly on future fighter engines. Dual-sourcing thus had valuable benefits beyond cost savings. And, in many cases, this argument extends down to the suppliers of the parts for the engines, thus multiplying the industrial base benefits.

The Conceptual Challenge in Interpreting Results From the Great Engine War

Critics of competitive dual-sourcing interpret the results from the great engine war very differently. Modern critics of competitive dual-sourcing look back on the performance of P&W and GE and suggest that GE was the more competitive firm. Their conclusion: if GE, the more cost-efficient firm, was awarded a single-source contract, then the government would have received even greater savings than it did under a competitive dual-sourced contract. The more efficient producer could produce more of that good, and there would be no need to bear the costs of maintaining a second line of production or a second supply line to support the second engine.

This interpretation of competitive dual-sourcing is misleading; it highlights the positive outcome achieved, while ignoring the conditions that made that outcome possible. When looking back, it

is important not to assume that the outcome is determined or certain. Before the Air Force even considered competitive dual-sourcing, it gave P&W several years to address its engine's quality concerns, which it proved incapable of doing in a timely manner. Yet, following the introduction of competition, both P&W and GE were able to make dramatic quality and performance improvements and move down the learning curve much faster than P&W did prior to the introduction of competition. The great engine war shows that competition in the production stage forces producers to make higher quality goods more efficiently than they would in a non-competitive environment.

Total System Competition

Littoral Combat Ship

The cornerstone of the U.S. Navy's Fleet Transformation is the Littoral Combat Ship (LCS), a high-speed, versatile ship that utilizes an innovative system of replaceable mission modules or pods that can be added or removed from the ship's hull prior to deployment. The operational concept of LCS is to provide a counter to anti-access and asymmetric forces in the littorals, such as pirates, submarines, mine deployment, and countermeasures. The LCS will also boast a mission module designed to launch and swallow special operations forces craft, greatly expanding the range of special operations. Moreover, the vessel's assigned helicopters, missiles, and cannons may be used against both shore and air targets.

The LCS concept began as the Navy's response to the high-profile USS *Cole* terrorist bombing in October 2000 and grew in significance following the September 11, 2001, attacks and the subsequent Global War on Terror (Taubman 2008). The LCS' RFP was released on November 1, 2001. From its conception, the LCS acquisition strategy was ambitious: the DoD wanted to acquire the LCS fleet in half the usual time for a major defense system (a prototype only six years after concept development and only two years of construction time per ship) at a bargain price of \$220 million per ship, and it wanted to reduce production costs through commercial-off-the-shelf technology and O&S costs through greater automation and fewer personnel requirements (Belva, 2010; Taubman, 2008). There is evidence that such technology reduces R&D costs and accelerates the design and production stages (Gansler & Lucyshyn, 2008).

In 2004, the U.S. Navy announced its plans to acquire prototypes from two separate contractors, Lockheed and General Dynamics, and announced that they would receive cost-plus contracts for the development of prototypes that would enable the two firms to compete for the entire production award of 55 LCS ships worth over \$12 billion (Taubman, 2008). While there were visible and significant differences between the two vessels, including the size and materials used, both vessels were compatible with the proposed system of modules.

Although the Department of the Navy (DoN) claimed that design changes reducing personnel requirements would make reducing O&S costs a program goal, the DoN never attempted to measure O&S costs using best practices (O'Rourke, 2010).⁴ Instead, the DoN relied on the O&S data for a surface class combatant ship, despite congressional frustration with the program's cost growth. In congressional testimony, the DoN's Assistant Secretary of the Navy (Research, Development, and Acquisition) Sean Stackey endorsed the CBO's estimate of LCS O&S costs (O'Rourke, 2010). The CBO suggested that O&S costs would constitute anywhere from 33% to 40% of total LCS life-cycle costs (Elmendorf, 2010).

Program Difficulties

By 2007, it was clear that there were significant program difficulties with the LCS. The emphasis on commercially available technologies led both firms to design their ships based on high-speed ferry models, but the Navy only later realized that such designs did not conform to the Navy's high safety standards. Additional military requirements and costly design changes mid-production drove up costs; in total, there were 600 significant engineering changes made to the ships in response to growing military requirements. Confusing and inaccurate DoD O&S cost estimates made total ownership costs unknown, as the DoN and CRS used O&S data from vessels with similar capabilities to predict O&S costs for LCS that were significantly below the data observed for LCS-1's O&S costs in the Visibility and Management of Operating and Support Costs (VAMOSOC) data system (Elmendorf, 2010). Finally, the Navy began to dither in its commitment to a winner-take-all production award (Belva, 2010; O'Rourke, 2010).

⁴ Best practices included "(1) analyzing the likelihood that the costs could be greater than estimated, (2) fully assessing how the estimate may change as key assumptions change, and (3) requesting an independent estimate and comparing it with the program estimate" (O'Rourke, 2010).

Subject to intense scrutiny, the DoN missed its self-imposed deadline in announcing the LCS contract award by the end of summer 2010 and postponed its decision until the end of the year in order to fully evaluate both bids. On December 29, 2010, the U.S. Navy announced that it would award a fixed-price incentive contract, split-buy production award to Lockheed Martin and General Dynamics, wherein both contractors would construct 10 additional vessels for a total of 20 LCS by 2015 (Department of the Navy, Office of Information, 2010). To date, the DoN has not announced what its future acquisition strategy will be for additional LCS, but it retains the option for future competition.

“This Is Going to be a Great Success Story”

After the first two prototypes had production costs in excess of 300% of initial cost estimates, many observers began to worry about program cost growth. Fortunately, the once-infamous program is now underway, and it is below initial cost estimates made in 2005. Navy Under Secretary Bob Work claimed victory, saying, “This is going to be a great success story. ... The average cost of the ships, when you add the amortized cost of our expected modules, is going to be about \$481 million in 2011 dollars” (Cavas, 2011). The initial estimate of \$400 million per ship in 2005, when adjusted for inflation, is the equivalent of \$489 million per ship in 2011 dollars. This recent announcement, when contrasted with the program difficulties mentioned previously, shows that both firms have moved down the learning curve at very fast rates, providing the government with the best results.

In retrospect, it is clear that the Navy accepted both firms’ cost estimates without seriously examining the performance shortcomings of selected commercial technologies, the costs of expanding mission requirements on the LCS program, and the full costs of an accelerated production schedule (Taubman, 2008).

Both vessels were expected to have roughly similar O&S costs of \$41–\$47 million per year, with the fuel used being the single largest contributor (O’Rourke, 2010) and personnel costs next. Assuming that each LCS has a lifespan of 30 years, O&S costs would constitute a higher percentage of life-cycle costs, approximately 50–55%, compared to the initial estimate of 33–40%. While the O&S costs were higher than initial estimates, the cost overruns were a result of exogenous factors: the additional costs of adequately training crew members for two classes of

high-tech ships and higher energy costs (O'Rourke, 2010). Neither of these factors was an indicator of substandard contractor performance.

In fact, personnel costs decreased due to expanded ship automation, resulting in significant savings compared to similar ships. This program goal was achieved in both ships, producing considerable savings from O&S when compared to similar vessels.

V. Missed Opportunities for Competitive Dual-Sourcing

When the DoD has utilized competitive dual-sourcing in its contracts, it has almost always received greater savings and increased performance as a result. The DoD has not been aggressive enough in utilizing competitive dual-sourcing, and the following two cases show some of the barriers to wider implementation of competitive dual-sourcing in the DoD.

Joint Strike Fighter Alternate Engine

The Joint Strike Fighter (JSF) Alternate Engine Program highlights the political challenges to maintaining competition throughout the acquisition cycle of a program. While the JSF Alternative Engine Program experienced competition between its first (P&W) and secondary (GE, Rolls Royce) sources, the second engine has been a source of political controversy throughout the program (Gertler, 2010; Sullivan, 2006).

The JSF, also known as the F-35, is a multirole stealth fighter currently under development that is on a trajectory to becoming the most widely used jet fighter ever built. The program is also the DoD's most expensive total aircraft program, at roughly \$407 billion over the program's life cycle⁵ (GAO, 2007). The JSF is being developed in three variants for the U.S. military: a conventional takeoff and landing aircraft for the Air Force, a carrier-capable version for the Navy, and a short takeoff and vertical landing variant for the Marine Corps.

The F-35A is the Air Force variant, a conventional takeoff and landing aircraft that will replace the F-16 and A-10 aircraft. The F-35C is the Navy variant, a carrier-based aircraft that will replace the F/A-18 (A, B, C, and D variants). Finally, the F-35B is the Marine Corps variant, a short takeoff and vertical landing aircraft that will replace its F/A-18s and the AV-8B Harrier (Lockheed Martin, 2010).

Although the program is primarily funded by the United States, it receives significant international support from U.S. allies, such as the United Kingdom, Australia, Canada, Italy, Denmark, The Netherlands, Norway, and Turkey (Gertler, 2010; "Israel's Barak Approves," 2010). Many of these allies are interested in acquiring their own F-35s, and future demand is

⁵ Dollars have been converted to FY2010 dollars.

likely from countries like Singapore, India, China/Taiwan, South Korea, Israel, Japan, and Saudi Arabia (AIRSHOW, 2009; Gertler, 2010; Malenic, 2009a). Planned foreign sales of the F-35 to sponsoring member countries total 646, but estimates of total foreign sales of the F-35 range from 700 to 3,500 planes, potentially exceeding total projected U.S. military purchases of 2,443 planes (GAO, 2007; Malenic, 2009a; Weisberger, 2009)

Unfortunately, some foreign buyers, such as Holland, are postponing purchases due to cost growth and quality concerns. The United Kingdom has threatened to withdraw its funding and support for the JSF program.

The alternative engine program is a joint enterprise between GE and Rolls Royce (UK), and it has received much political support from the British government (DoD, 2008).

Engine Competition Concerns

The JSF program sponsored competition between aircraft designs from the start of the program through the technology development phase. Competition between engines—the most significant cost factor for an aircraft’s life-cycle costs—essentially halted in 1996 when the two remaining prototypes in the competition, the Lockheed Martin X-35 and the Boeing X-32, used the same engine, the P&W F-135.

In the FY1996 Defense Authorization Act, Congress responded by providing funding for an Alternate Engine Program. Its intent was to provide “adequate engine competition” that could lower prices.

Cost Growth and Elimination of the JSF Alternate Engine Program

The JSF program has experienced cost-growth difficulties throughout its development. By 2009, P&W reported that the cost of its engine, the F135, had jumped from \$6.7 million to \$8.3 million (FY2009), a 24% increase (Capaccio, 2009; Gertler, 2010). On March 20, 2010, the DoD formally announced that the JSF program will breach Nunn–McCurdy unit cost limits,⁶ requiring

⁶ The Nunn–McCurdy Amendment requires congressional notification if the program acquisition unit cost (PAUC) or average procurement unit cost (APOC) exceeds the current baseline by 15% or the original baseline by 30%. If

the USD(AT&L) to certify the program and to include the new unit cost estimate for the JSF program as reasonable (Gertler, 2010). Cost growth has continued as the program has had difficulty maturing technologies in development, including the F-135 engine—particularly for the F-35B variant, where increasing aircraft weight jeopardized the future potential evolution of the aircraft (Murch & Bolkcom, 2009).

While initially a proponent of the program, the Bush Administration in FYs 2007, 2008, 2009, and the Obama Administration in FYs 2010 and 2011 have sought to eliminate the alternative engine program, believing that “savings from competition would not be offset by high upfront costs” (Gertler, 2010; Office of Management and Budget [OMB], 2009). On February 16, 2011, the House of Representatives voted to end funding for the JSF Alternate Engine Program.

Independent Cost Studies

Three independent cost studies were conducted, and all of the studies agreed that there were significant nonmonetary benefits that could be gained from the Alternate Engine Program. These included improved contractor responsiveness, maintaining the industrial base for fighter engine technology, enhancing readiness, instilling contractor incentives for better performance, ensuring an operational alternative if the current engine developed problems, and enhancing international participation.

The studies identified a range of savings required to breakeven (10.3% in the GAO, 2007, study, 18% in the IDA study, and 25.6% in the study by DoD’s Cost Analysis Improvement Group [CAIG], 2007; Murch & Bolkcom, 2009). Based on congressional testimony, the differences principally arose from dissimilar estimates of funding Component Improvement Programs (CIPs) for the engines (Murch & Bolkcom, 2009). The GAO assumed that competitive pressure would drive contractors to improve without additional funding; the other two studies included CIP funding.

All three studies used the same estimate of the number of JSF to be built for the DoD: 2,443 planes. Cost savings will necessarily increase with each additional plane, and, as a result, larger

the PAUC or APUC exceeds 25% of the current baseline (or 50% of the original baseline), the breach is critical and the program must be recertified by the USD(AT&L).

orders of planes result in increased total savings. The estimated number of planes is deceptively small for two reasons. First, if the JSF replaces the F-16 jet fighter, as some defense analysts predict, then the orders for the JSF may be significantly higher. Second, the U.S. is not the only purchaser of the JSF; over 20 countries have already announced their interest in purchasing several hundred additional planes. Over the program's life span, the number of foreign JSF sales may exceed domestic U.S. sales. If foreign sales of the F-16s are any indication, then the JSF may prove highly popular overseas. As the total number of planes to be produced mushrooms, the benefits from dual-sourcing increase as well.

Previous attempts at competing aircraft propulsion systems have resulted in significantly reduced life-cycle costs: the F-16 engine demonstrated a total program savings rate of 21% (GAO, 2007). If a similar rate of savings were achieved for the JSF, there would be net savings for two out of the three analyses. Sustainment costs would be the same for either scenario since the number of aircraft and cost per flight hour would be the same. More important, the GAO estimated that the additional sustainment costs under a dual-sourced program, including spares, training, and manpower, represented an increase of only \$127 million out of a total program cost of \$407 billion (GAO, 2007). The additional sustainment costs were quite small in relation to the expected life-cycle savings from O&S. With a savings rate of 10.3–12.3%, however, a dual-sourced program would provide cost benefits that exceeded the initial costs of funding the Alternate Engine Program as well as the additional sustainment costs from competitive dual-sourcing (GAO, 2007).

Finally, the CAIG (2007) report highlighted the fact that based on the weight growth projection of the STOVL variant, the P&W F135 engine would require a major upgrade (beyond that of the F136) to provide the required thrust (Murch & Bolkcom, 2009). This would obviously change their breakeven point analysis, making competitive dual-sourcing more attractive.

Outcome

The DoD missed an excellent opportunity to achieve important qualitative benefits like improved performance as well as significant savings in O&S costs through the Alternate Engine Program. It is believed that the DoD was too risk-averse with respect to dual-sourcing, and overlooked ways that it could benefit from increased competition. In early 2011, GE/Rolls Royce offered to

renew their alternative engine program under firm-fixed-price contracts. This offer was mostly symbolic, as firm-fixed-price contracts do not ensure cost savings (cost growth is still possible through renegotiated contracts), but it reflects the contractor's willingness to compete as well as entertain new approaches to contracting requirements. The government could have considered an approach similar to the way it funded the Tomahawk program's second source. Because GE/RR stand to benefit from increased competition, the government could offer a combination of loans and grants to continue the Alternative Engine Program. The contractor would repay some of those loans out of its profits from manufacturing (especially from its foreign sales), and it would undoubtedly spend its own money more carefully than the government's. In this way, the government is an investor as well as a consumer in the defense industry, receiving a modest return for its investment. Creative solutions like these were not considered; instead, the question revolved around whether short-run accounting showed an increase or a decrease in program costs for the Alternative Engine Program. Thus, GE offered in mid-2011 to invest its own money if the competitive program was approved.

Additionally, foreign sales for the F-35 may exceed domestic sales, and this is not at all an anomaly in an increasingly global defense market. The defense market is not as monopsonist as previous acquisitions literature has suggested. Defense contractors generally receive favorable terms from the government, and then turn around and sell (generally) less capable versions of U.S. military hardware (and software) to foreign powers. The U.S. government should consider the international ramifications of major weapons systems and their impact on international trade, U.S. and foreign military relations, and the global market for defense systems. In this sense, the F-35 is not unusual in that its projected foreign sales may exceed U.S. DoD purchases. By funding the Alternative Engine Program, the F-35 engine would provide better quality and value to all potential customers, foreign and domestic.

Air Force KC-X Tanker

One of the Air Force's most important capabilities is force projection, providing the strategic and logistical flexibility to strike anywhere in the world. Two trends also make long distance force projection a top priority for the DoD in the 21st century. First, political and budgetary factors are shrinking the number of U.S. air bases located overseas, limiting the reach of U.S. planes.

Second, recent technological advances in missiles (like China and Iran's anti-ship missiles) may force aircraft carrier fleets to operate farther from areas of interest and may also make some airbases more vulnerable to missile attack. The Air Force's aerial refueling capacity enables aircraft to fly farther from airbases and aircraft carriers, increasing the military's logistical and attack capabilities while minimizing the danger to U.S. personnel.

In summary, aerial refueling is a critical enabler of U.S. power projections, making possible the rapid deployment of forces in response to contingencies and significantly increasing airpower employment options. In addition, aerial refueling capability is still critical to the nation's strategic nuclear mission (i.e., the bomber leg of U.S. nuclear forces, as well as other strategic missions, such as the airborne command post). Thus, in late 1990s it was the number one priority of the Air Force's acquisition program. Yet, the acquisition of air refueling tankers to replace the Air Force's aging fleet of KC-135s was one of the most drawn out and controversial acquisitions made by the DoD in this past century.

The current Air Force fleet has approximately 600 tankers, of which 531 tankers are Boeing KC-135 and 59 are Boeing KC-10A. The KC-135 can carry 200,000 lbs. of fuel, while the KC-10 can carry 356,000 lbs. of fuel, almost twice as much as the KC-135. Moreover, the average age of the KC-135 is over 48 years, almost twice as old as the KC-10 (which is about 20 years old).

Currently, the Air Force relies on its fleet of aging KC-135s to provide much of its aerial refueling capacity. First introduced in 1957, the Air Force continues to operate over 450 of these Boeing-built aircraft. Today, the KC-135s fleet is approaching the end of its intended lifespan of 50 years (Gordon, 2008). The O&S costs for the KC-135 are prohibitively expensive, as older planes require significantly more maintenance to operate. In 2001, the Air Force reported that the KC-135 fleet would incur "significant cost increases" between 2001 and 2040, and, at that time, they began to conduct an analysis of alternatives (AOA) to determine the optimal replacement option for KC-135s. The initial plan was to begin recapitalization in 2012 to meet the KC-135's 2040 planned retirement (Bolkcom, 2007).

Modernizing or replacing the current fleet of tankers has been an issue for the U.S. Air Force and the DoD for more than a decade. In 1996, the General Accounting Office (now the Government Accountability Office, or GAO) reported that the long-term viability of the KC-135 fleet was in

jeopardy and urged the immediate studying of replacement options. The Air Force and the DoD developed a strategy to lease 100 Boeing KC-767 aircraft to replace the oldest KC-135Es, but this proposal caused a significant controversy. In FY2002 Congress authorized the Air Force (see § 8159 of the FY2002 DoD Appropriations Act [P.L. 107-117]) to lease 100 Boeing KC-767 aircraft to replace the oldest KC-135Es. In 2003, the Air Force awarded Boeing a contract to lease 100 Boeing KC-767 aircraft for six years at a total price tag of \$12.3 billion (in 2002 dollars; Curtin 2003). After six years, the Air Force would have the option of purchasing the aircraft (for \$44 million each). The GAO estimated that the cost of leasing the aircraft was significantly more expensive than purchasing the planes (including their O&S costs; Curtin, 2003). Due to congressional protests over the unacceptably high cost of leasing KC-767s, the contract was modified in November 2003 so that the Air Force would lease only 20 aircraft and would purchase the remaining 80 planes. Finally, when a major procurement ethics scandal involving the Air Force and Boeing was exposed, the lease option was removed from consideration (Bolkcom, 2007).

In January 2007, the Air Force issued a new RFP for a replacement tanker. Two firms submitted proposals by the April 2007 deadline: Boeing, and a partnership between Northrop Grumman (NG) and the European Aeronautic Defense and Space Company (EADS), the parent of Airbus. Boeing offered the KC-767, based on the Boeing 767-200 Long Range Freighter, while the NG/EADS partnership offered the KC-30, based on the Airbus A330 Multirole Tanker Transport. Both planes had commercial equivalents, and the cost of maintaining supply lines for their O&S needs would have been smaller than they would have been for a new design (Gansler & Lucyshyn, 2006).

In February 2008, the Air Force declared the NG/EADS team the winner of the competition. Boeing promptly filed a protest with the GAO, and in June 2008 the GAO sustained the protest. Subsequent to the GAO decision, the Air Force decided to issue a new RFP.

In March 2010, NG made the decision not to submit a proposal in response to the new RFP, “citing a US Air Force request for proposal (RFP) it believes is weighted in favour of its competitor [Boeing]” (Ostrower, 2010). One month later, EADS announced that it would submit a proposal on its own (Hicks, 2010). The competition reached a fever pitch when the World

Trade Organization ruled in March 2010 that EADS received improper subsidies for its planes, amplifying the congressional calls for the DoD to award the contract to Boeing. Whether this ruling determined the outcome of the contract decision is unknown, because in 2008 the DoD's then USD(AT&L) John Young stated,

[T]he government procurement regulations and laws don't give us mechanisms nor do they seek for us to evaluate a range of factors outside of the primary factor. And that is, take the military's requirement, ask for proposals that meet those requirements and try to get a best value solution using the tax payers' dollars. That's what we're going to do. (Young, 2008)

Draft and Final KC-X Contracts Compared

The USAF's final KC-X RFP in 2010 differed significantly from its 2009 draft proposal (see Figure 15).

Major Differences Between KC-X Draft and Final RFP

Issue	Draft RFP	Final RFP
Microwave Landing System	Required.	Not required.
Large Aircraft Infrared Countermeasures	Contractor to procure and include in price.	Government will furnish.
Contract Type	Development phase: Fixed-price with incentive fee.	Development phase unchanged.
	Production lots 1-2: Firm fixed price.	Production lots 1-2 unchanged.
	Production lots 3-5: Firm fixed price, with 5% inflation trigger for price adjustment.	Production lots 3-5: Not to Exceed, with 2.5% inflation trigger.
	Production lots 6-13: Not to Exceed, with 5% trigger.	Production lots 6-13: Not to Exceed, with 1% trigger.
	Contractor support: Firm fixed price.	Contractor support unchanged.
Mission modeling	Integrated Fleet Air Refueling Assessment (IFARA) model used to determine operational suitability.	IFARA ground rules updated “to ensure they reflected current operational practices.”
Alert quick-start	Did not specify temperatures at which power carts were allowed for environmental control.	Established a range of temperatures for which power carts could be allowed for both heating and cooling the aircraft.

Figure 15: Major Differences Between KC-X Draft and Final RFP
Source: (Gertler, 2010)

Competitive Dual-Sourcing Option

Although several politicians as well as researchers (including the authors of this paper, CPPPE) have suggested that the tanker program be dual-sourced, so that the Air Force would make competitive awards for both the Boeing KC-767 and the NG/EADS KC-30 (e.g., using split buys for each lot) in order to maintain competition throughout the life cycle, the Air Force and senior DoD officials publicly opposed such proposals.

Competitive dual-sourcing would have been very attractive for the air tanker because dual-sourcing provides the Air Force the “opportunity to capitalize on commercial aircraft producer and customer investment” by purchasing an item that is very similar to the commercial-off-the-shelf product (Gansler, 2007). Because the commercial versions of these two aircraft have been in service for years, and militarized versions would not differ substantially from the commercial versions, the initial and recurring production costs associated with split production would have been minimized. In fact, given the greater size of each collective build lot (combining commercial and military buys), economies of scale reduce the production cost of the aircraft when compared to unique military purchase.

For similar reasons, the O&S costs of maintaining two different kinds of aircraft would have been minimal. Since these are both commercial aircraft, a world-wide commercial network already exists to provide spare parts, maintenance, and repair. As the number of planes using these global supply chains increases, the costs of providing O&S services will decline on a per unit basis as well.

Given the civil/military nature of the aircraft and the large monetary size of the buy, the firms have continuous pressure to offer the Air Force the best value. Major logistics services companies, such as FedEx Corporation and the United Parcel Service, maintain mixed Boeing-Airbus fleets for the same reason: to benefit from competition. On the basis of our prior analysis, we believe that the Air Force could have saved billions of dollars and achieved improved performance through the use of competitive dual-sourcing (Gansler & Lucyshyn, 2006).

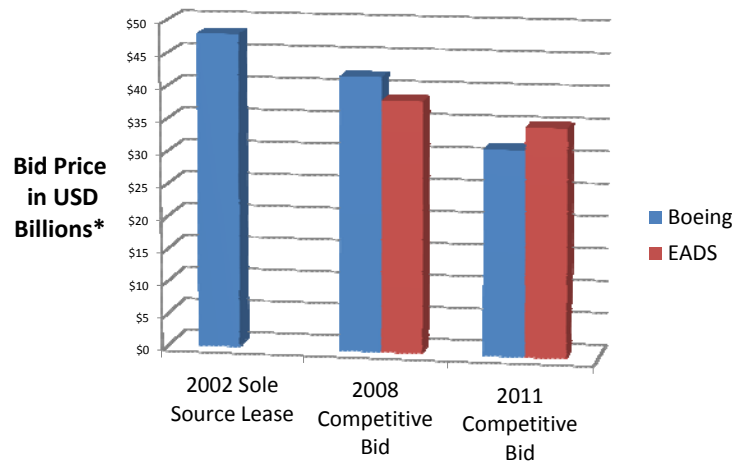
Contract Award and Missed Opportunities

On February 24, 2011, the DoD awarded a single-source, firm-fixed-price, \$35 billion contract to Boeing for initial production of its KC-46A, a remodeled variant of Boeing's 767 (DeYoung & Pincus, 2011). The contract may be the largest single defense contract to be awarded in several years and is expected to produce as many as 50,000 jobs. As both planes met the military's 372 requirements, the decision was made by the significant differences in life-cycle costs between the two planes. Boeing's smaller plane was expected to use considerably less fuel per flight hour, which, on the surface, suggests that the Boeing plane would have lower life-cycle costs. This assessment is somewhat misleading; EADS' Airbus also had a much larger capacity for fuel storage, enabling it to refuel an aircraft squadron with fewer air tankers than would have been possible for Boeing's remodeled 767.

While the contract with Boeing is for a firm-fixed-price of \$35 billion, this is no guarantee that the contract is immune to future cost growth. The history of DoD acquisitions suggests that cost growth for major defense systems is just as likely for fixed-price contracts as cost-plus contracts. (For example, both the F-111 and C-5 programs used fixed-price contracts during development; yet they represent two of the largest cost growths in DoD history, with the justification based on the very large number of government-requested changes imposed as the programs evolved.) Consequently, there is good reason to believe that without the competitive pressure from EADS, Boeing may prove less efficient than the learning curve would suggest, and program costs will increase.

The benefit of competitive pressure is evident by the bid history depicted in Figure 16. The winning Boeing proposal was approximately 33% less than the original sole-source lease proposal, vividly demonstrating the value of competition. It will be interesting to watch the program costs now that there is no more competitive pressure.

Bid History on The Air Force Tanker



* Bid prices adjusted for escalation, changes in requirements, and aircraft quantities

Figure 16: Bid History of the Air Force Tanker

Source: (Oliver, 2011)

We believe the KC-X Air Force tanker program was an ideal candidate for competitive dual-sourcing, economically and politically (even in terms of U.S. employment since the plan was to build the EADS tanker in Alabama). Because the costs of maintaining a second line of production as well as a second supply chain are minimal in cases with two commercial equivalents, competitive dual-sourcing between EADS and Boeing would have been a good decision economically and politically. The DoD would have received improved value, performance, and reliability under competitive dual-sourcing, and it would have done so at bargain prices. Moreover, dual-sourcing, in this case, would have been politically attractive since it would have demonstrated an increased willingness to work with foreign firms while supporting the domestically located defense industry.

Moreover, O&S costs are lower for defense systems when commercial equivalents are available. Not only is it easier to provide O&S cost estimates for defense systems with commercial equivalents but also it is feasible to design firm-fixed-price contracts with incentives that provide the government with reduced risk of cost growth. Additionally, the competitive pressure during production works to reduce procurement costs as well as sustainment costs. Competitive dual-

sourcing when a commercial equivalent is available is ideal because the defense system experiences the benefits of competition on innovation and cost reduction while minimizing the additional costs of dual-sourcing.

VI. Conclusions

The DoD Faces an Increasingly Challenging Acquisition Environment

Cost growth for defense acquisition programs is, and has been, a prominent issue for the DoD. The DoD's programs have typically experienced high cost growth. Despite warnings of acquisition difficulties dating back to the 1950s, acquisition outcomes have not improved substantially over the past six decades. Moreover, many cost estimates for defense systems underestimate O&S costs and are not performed to highlight the long-term cost increases of expanded military requirements. These O&S costs represent a significant and growing portion of the DoD's expenditures, and they are expected to rise significantly in the near future due to a number of factors, including increased operational use, ageing military infrastructure and equipment, and increased technological complexity. Given the size and importance of these costs, continued growth may limit the DoD's ability to achieve its security objectives in the future.

Given these rising O&S costs, the DoD has only recently started to prioritize low life-cycle costs or O&S costs as a system requirement. As is widely observed, the DoD often does not prioritize affordability: "the conventional wisdom is that when programs experience difficulties, expenditure is the first constraint to be relaxed and schedule the second, but that performance goals are adhered to quite rigorously, with the result that the unit price of the product increases" (Arena & Birkler, 2009). By not prioritizing affordability, the DoD has often committed itself to higher life-cycle costs than it should have to pay. Life-cycle costs were often not considered until a program's production phase. If costs were a consideration, attaining a cost goal was often given a lower priority than meeting other objectives such as performance. Given that these early decisions generally determined later expenditures, the DoD experienced much higher O&S costs than may have been possible.

Competition Provides Significant Benefits During All Phases

Competition is an effective way to ensure the best acquisition outcomes. The government currently expends considerable resources to monitor program costs. In the private market, firms rely on competition—based on price, not cost—and minimal oversight to achieve efficient

outcomes. Although the military market does not always reflect a perfectly competitive market, the DoD could make greater use of competition—and commercial markets—to achieve more efficient outcomes. More important, numerous studies have shown that competition is effective at reducing life-cycle costs in both the military and commercial sectors. The studies cited in this research have found savings in the range of 12%–52% for military programs. However, the gains from quality and durability improvements under competition are frequently ignored in these studies, yet resulting in greater value for each dollar spent. As a result, these studies likely underestimate potential life-cycle cost savings by not fully accounting for cost savings and avoidance that occurs throughout a program’s entire life cycle.

Competition allows the DoD to share acquisition risks with firms. Under most sole-source contracts, the DoD is fiscally responsible for the vast majority of cost growth that occurs. Even with a fixed-price contract, programs tend to undergo numerous design changes that can significantly increase the cost of the program—even though the design change might be necessary to achieve the performance parameters the DoD originally contracted for. Without competition, monopoly firms have few incentives to curtail cost growth, implement decisions that would ultimately reduce the DoD’s life-cycle cost of a system, or devote additional internal resources to fulfill the contract. By contrast, competition enables “a basic shift in relative power that increases the contractors’ responsiveness and reduces the ... [military Services’] cost of monitoring their contract compliance” (Camm, 1993).

Competition also provides firms the incentive to continue to move down the learning curve, which does not exist with most sole-source acquisitions. Competition encourages firms to put forth their best efforts by offering the opportunity to capture a larger share of the market because by not doing so, the firm could lose market share and eventually be forced to close. Further, competition results in continuous improvements. Competition provides the DoD with higher performance but lower cost systems over time. Unlike in a sole-source environment, firms typically implement such development without a significant contribution of funds from the DoD. As a result, the DoD receives better performance at a lower price—a concept that runs counter to the traditional DoD view that it must pay a higher price to receive higher performance or quality (Gansler & Lucyshyn, 2008).

Finally, by introducing competition into the production phase, and adapting contractual agreements to emphasize quality, the DoD has been able to achieve higher reliability. Higher reliability results in fewer failures and less maintenance when a system is used. In addition to increasing the availability of systems, improved reliability decreases O&S costs.

Competition During Production Can Reduce O&S Costs

In the past, competitive dual-sourcing has often been used to address performance concerns or contractor unresponsiveness, not cost reduction. For the Tomahawk missiles and P&W F100/GE F110 engine, the performance improvement targeted was reliability. In both examples, reliability problems were addressed with design modifications that increased reliability and decreased the system's overall price through lower O&S costs. For both of these examples, the government grew frustrated with the single-source contractor's unresponsiveness to government demands, namely, to address serious quality/reliability concerns. Competition during production, was rarely implemented at the beginning of the production stage with the explicit goal of reducing program costs. Thus, competitive dual-sourcing is rarely practiced by the DoD, and it is frequently misunderstood by those outside acquisition circles, such as members of the media or elected officials (who often claim, "it is wasteful to have two sources; just manage the single source better").

Competitive dual-sourcing is effective at reducing program costs for build-to-print defense system contracts. Quality and durability improvements mean that systems have longer life-spans and need to be tested less frequently (testing consumes equipment as well as manpower), all of which has a significant effect on O&S costs. Longer life-spans and less frequent testing result in fewer units demanded as well as less manpower spent, resulting in significant O&S savings. Additionally, systems that experience competition during production also reduce the unit cost, resulting in large net savings during production.

Competitive dual-sourcing is also effective at reducing program costs for defense subsystem production contracts, especially when the component constitutes a large portion of O&S costs. The great engine war is a dramatic example of how competitive dual-sourcing can reduce program costs for component production contracts. Since jet engines constitute a large portion of the aircraft's O&S costs, quality and durability improvements mean that engines have longer

life-spans and need maintenance less frequently. Additionally, components also are less expensive to produce, resulting in further savings during production, as well as broadening the defense industrial base at the lower tiers.

The DoD often ceases competition in the short-term due to short-run budgetary considerations. Many programs cease competition at the end of the development phase. Although not widely acknowledged, many programs' second source is usually canceled prior to the production stage because competitive dual-sourcing requires added upfront costs. In this way, ceasing competition becomes a way for policymakers to claim credit for cutting the budget, while indirectly contributing to higher long-term program costs. This concern has been, at least, partially addressed by the Weapon Systems Acquisition Reform Act of 2009, which requires consideration of cost throughout the life cycle and provides a stronger mandate for the DoD to maintain the option of competition throughout a program's life cycle.

Barriers to Implementation of Cost-Effective Competition

There are many barriers to implementing effective competitive dual-sourcing for defense systems, including defense industry consolidations, high barriers to market entry, and regulatory and statutory preferences for domestic firms. Consolidation of the defense industry means fewer defense contractors and less competition, making it harder for the government to receive best value. High barriers to market entry reduce competition by preventing privately successful firms from competing with established defense contractors. Regulatory and statutory preferences for domestic firms prevent foreign firms from competing on an equal basis, further reducing the number of potential defense contractors.

Despite all of these barriers, the greatest barrier to competitive dual-sourcing is conceptual. This form of competition requires upfront costs and savings that gradually accumulate over time. As noted by a number of observers, "the costs of competition are short-term and clear, but the benefits are long-term and uncertain" (Arena & Birkler, 2009). Additionally, the savings from dual-sourcing will be apparent only to those who are somewhat experienced in defense acquisitions. Savings are determined by comparing annual unit O&S costs with the annual unit O&S costs of similar defense systems, multiplying this by the total number of systems to be purchased, and then multiplying this result by the expected lifespan of the defense system.

Savings are decidedly less straightforward than calculating upfront costs. Although the total program savings may be much larger than the initial cost of maintaining a second line of production, the long-term benefits are abstract while the upfront costs are concrete. But, of course, the benefits become very real over time.

There is an abundance of data on contract outcomes that can be used to estimate the benefits of competitive dual-sourcing, but these estimates are less certain than the upfront costs required to implement dual-sourcing.⁷ Moreover, the projected costs without competition are generally estimated based on optimistic projections, which are rarely achieved. Since the senior political leadership tends to be risk-adverse and focused on short-term budget fluctuations (they have strong incentives to adhere to short-term goals), the DoD often does not take advantage of predicted long-term benefits. Even with accurate cost projections, the DoD has a limited ability to model life-cycle cost impacts and perform appropriate cost benefit analysis. As a result, the DoD is not able to properly forecast the outcome of decisions made today on a program or the DoD in the future, which in turn means that decision-makers often make suboptimal choices.

⁷ This is always a source of contention since the benefits are always compared to program projections and cannot be definitively measured, until later.

VII. Recommendations

- **The Under Secretary of Defense for Acquisition, Technology, and Logistics should encourage greater use of competitive dual-sourcing.**

Competitive dual-sourcing is poorly understood outside of acquisition circles, and it is particularly difficult to explain to skeptical elected officials and journalists. The costs of competitive dual-sourcing are both upfront and certain, and the benefits are long-term and approximate. Much of the popular debate in Congress and the media revolves around procurement costs of defense systems, whereas there is virtually no discussion of rising O&S costs. The USD(AT&L) must explain to skeptics that competitive dual-sourcing is a proven, effective approach to reducing both procurement costs and O&S costs.

Although competitive dual-sourcing may not be appropriate for every production contract for a defense system, for those programs in which it is cost effective, the use of competitive dual-sourcing represents a clear source of untapped savings in the DoD's long-term budget. Despite the DoD's previous success in utilizing competitive dual-sourcing, it has not developed a consistent or coherent policy that encourages the use of competitive dual-sourcing. The USD(AT&L) should be an active proponent, encouraging the use of competitive dual-sourcing, signaling the DoD's new policy to acquisition specialists as well as government contractors.

- **Whenever possible, the DoD should reserve the right to add a second source and convert to a competitive dual-source contract to ensure that the contractor provides best effort and responsiveness to DoD queries, requests, and requirements.**

While the DoD has been successful in motivating primary- and second-source contractors to provide their best effort through winner-take-all (WTA) production awards, it should be careful not to risk reducing contractor responsiveness. In order to keep firms responsive to the government, it should contractually retain the right to add a second source or convert to a dual-source, split-buy contract if it believes that the contractor is

not providing its best effort. The WTA production award is intended to reward the contractor for good performance, not to enable bad performance.

- **When using competitive dual-sourcing, the DoD should address cost growth and quality concerns through the adoption of manufacturer warranties and post-production incentives, preferably in the development phase.**

Warranties provide a positive incentive by rewarding the contractor for high levels of reliability post-production. When quality concerns are an issue, the DoD should use such incentives to ensure that it receives the desired level of quality for defense systems.

- **The DoD must overcome internal barriers to embrace the Weapon Systems Acquisition Reform Act of 2009, specifically its competition clauses.**

Despite sound acquisition policies, the DoD still experiences significant acquisition difficulties. In large part, these problems stem from the DoD's cultural resistance to fully implement and internalize mandated acquisition policies. DoD leadership must embrace the intent of the law in order to deliver better outcomes for DoD acquisitions, especially the recently passed Weapon Systems Acquisition Reform Act of 2009.

- **Competitive dual-sourcing contracts should provide firms proper incentives to prioritize low-cost designs.**

Firms play a vital part in determining a program's life-cycle costs. In addition to the competitive pressure, the DoD should incorporate into its contracts strong incentives to prioritize continuous improvement processes that improve performance and lower life-cycle cost. For example, the DoD could offer firms a percentage of program savings on an indexed scale so that the more the firm reduces its life-cycle costs, the more profits the firm will make.

- **Congress should work to reduce barriers that limit the production of military products in a “dual-use” fashion, along with commercial products.**

At present, there are many barriers (legislative, regulatory, etc.) that inhibit firms from producing military products for the DoD on the same production lines in which commercial items are produced—even if the item acquired is similar or identical. These barriers include specialized cost accounting rules, export controls, intellectual property rights, government-unique “flow down” requirements to lower-tier suppliers, and so forth. It makes economic and strategic sense (in terms of low cost, high quality, rapid response, surge capability, reduced overheads, etc.) to combine commercial and military engineering, production, and support in the same operations. But to do so requires the removal of the previously noted barriers. Now, more than ever, new technologies utilized in factories allow for flexible production. By allowing military items to be produced along with their commercial counterparts, competitive dual-sourcing could be used more frequently and more affordably (in terms of upfront costs).

Conclusion

Increasing pressure on defense policymakers to cut the DoD’s FY2012 budget represents a unique opportunity to reevaluate the way that the DoD acquires defense systems. As our allies grow increasingly dependent on American military capabilities for enhancing international security, it is critical that America reduce the size of its defense budget in a responsible manner. Reforming defense acquisitions by expanding its use of competitive dual-sourcing provides a long-term source of savings to the DoD without sacrificing needed military capabilities.

Competitive dual-sourcing has the potential to reduce production costs and O&S costs by incentivizing contractors to work more efficiently and invest in quality/reliability improvements, all of which enables the government to do more with less. By enabling continuous competition, defense contractors can capitalize on the same efficiency gains and performance improvements that firms in the private sector routinely provide. The DoD may be in a budgetary crisis, but it is also facing an opportunity for meaningful acquisition reform that should not be put off.

Appendix I: Candidate Programs for Competitive Production

As noted in this research, competition during the production phase is more likely to produce cost savings that overcome the additional expenditures needed to maintain competition if the product has certain characteristics. Candidate programs for competitive dual-sourcing are listed below by category. Only programs that have not yet entered into the production phase are considered as candidate programs:

(a) A high-cost, high-quantity item

1. Airplane engines, such as the Joint Strike Fighter Alternative Engine
2. Munitions, such as the Excalibur Precision Guided Extended Range Artillery Projectile, Joint Air-to-Surface Standoff Missile (JASSM) and Joint Air-to-Ground Missile (JAGM)
3. Unmanned systems
4. Many ground vehicles, such as the Joint Light Tactical Vehicle (JLTV) and the Ground Combat Vehicle (GCV) Infantry Fighting Vehicle (IFV)

(b) A low-cost, high-quantity commodity

1. Performance-based logistics programs that focus on specific commodities such as tires, batteries, or certain repair parts
2. Communications equipment, such as the Joint Tactical Radio System and components

(c) A product that exhibits high interoperability with a commercial-sector equivalent

1. Airlift capability, particularly to replace systems that will not be required to take-off and land in adverse conditions
2. Supply chain helicopters
3. Future tanker

4. Supply chain ground vehicles

5. Information systems

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