Competition and the USAF's Tanker Replacement Program

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Table of Contents

Executive Summary

How to structure the air refueling tanker replacement program is one of the most important procurement decisions currently facing the United States Air Force and the Department of Defense. We believe, on the basis of our findings, that since the candidate replacement tankers are both in commercial production, this procurement presents the DoD with an exceptional opportunity to maintain two production sources, and use competitive pressure to obtain the best value for the Air Force (i.e. a savings of over $7 billion; with improved performance)..

Background

The Air Force fleet has approximately 600 tankers, but most of them are over 40 years old. The Air Force needs a program to begin replacing the older tankers with new, more advanced aircraft in order to support the global expeditionary missions. In 2001, DoD authorized the Air Force to lease 100 Boeing KC-767 aircraft to replace the oldest KC-135Es, but this proposal caused a significant controversy among policymakers, and was abandoned after a major Air Force acquisition ethics sandal. The replacement tanker acquisition presents several questions, which include:

- How does competition impact weapon system acquisition and what form should it take (e.g. for an award, or during implementation)?
- Are the benefits of continuous competition derived from dual-sourcing greater than the costs of developing and maintaining the dual capability?
- How does the globalized defense industry affect the U.S. industrial base?
- What role should the government play in the natural evolution of the industrial structure and capabilities?
- Is dual-sourcing the tanker replacement a reasonable option?

With this report, we attempt to provide some insight into these questions.

Competition in DoD Acquisition

Although competition is a driving force in the US economy, the unique structure of the defense market, with its recent consolidations, makes the introduction of competition into the acquisition of DoD weapon systems challenging. In particular, the barriers for new firms to enter the defense industry, that include knowledge of the federal acquisition regulations, specialized accounting and reporting procedures, the need for security clearances, and the political considerations, are extremely high. Nonetheless, DoD does strive to introduce competition, with varying degrees of success, through the four stages of system acquisition. These stages are: 1) competition for development, 2) competition during development, 3) competition for production, and 4) competition during production (with or without follow-on support).

Previous studies have demonstrated that continuous competition throughout production has proven to have significant benefits, to include net savings ranging from 12 to 50 percent. In addition, when competition is introduced during production the second source generally achieves a steeper learning curve. This is followed by an immediate shift downward in the original producer's learning curve, accompanied by a steepening or "rotation" of the original source's learning curve. As a result of the competitive incentive, competition has been shown to drive both producers to greater efficiency. When one considers how competition impacts the cost of aircraft programs specifically, DoD programs with no production competition have been found to increase an average of 46 percent (in a sole-source environment). This is contrasted to commercial aircraft programs produced in a competitive environment, with an average program **decrease** of 16 percent.

When buying major weapon systems the federal government is easily classified as a monopsonist (i.e. a sole buyer). A question that naturally arises is why the government uses its monopsony power so sparingly. Although the government, as a monopsonist, can theoretically wield significant power, for various reasons, it generally uses its monopsony power in a limited way. First, the federal government is not a single (unitary) decision maker (there are many government stakeholders and individual program buyers).

Second, although federal acquisition regulations provide acquisition officials with powerful tools to ensure contractors charge reasonable prices, contractors do retain an important measure of discretion to exploit superior information (especially if they are sole-sources). Third, the inherent nature of many participants with contradictory objectives, such as, the military's desire for higher performance, the budget's people desire for a lower cost, innovation, and the procurement's people desire for competition, makes it even more difficult to use government's monopsony power.

On the other hand, from the supply side, the small number of sellers in the defense market forms an oligopoly. In many cases, this oligopoly is designing innovative, new products, for which there is no production experience; and at prices for which there is little precedent. Other factors outside the control of the government, such as rapidly-changing technology, unpredictable world conditions, new defense strategies, changing threats, uncertain future funding, and politics, can significantly influence the market. In many respects, this oligopoly faces an environment very different from the commercial marketplace. Using a framework, developed by Harvard Business School Professor, Michael Porter, and based on the empirical data contained herein, we conclude that the government must maintain competition to balance the power of the supplier oligopoly.

Cases

We reviewed three "example" case studies to illustrate the benefits of a variety of considerations when introducing competition. "The Great Engine War" and the Tomahawk are classic examples of weapon system programs in which competition was successfully applied during production. These programs resulted in improved performance and increased reliability, as well as net program savings. The Joint Strike Fighter (JSF) case demonstrates that competition at the system level is not necessarily always the best choice. Establishing a second production source would require a significant investment of non-recurring costs, which would not be fully recovered through the savings that would result from production competitions. However, the JSF program has developed a strategy to maintain competitive pressure at the major subsystem level (where the high-cost and high-risk elements reside). These cases are followed by an in-depth analysis of the acquisition strategy for the tanker replacement program.

Replacing the Air Force Tanker

The U.S. Air Force has, in the recent past, explored a number of options for maintaining and improving the aging tanker fleet. However, the operations and maintenance costs, and time undergoing depot maintenance, are expected to continue increasing; making many agree that the fleet needs to be modernized. The plan originally pursued by the Air Force was to lease 100 Boeing 767 tankers. The cost of leasing was valued at $29.4 billion which was $4.4 billion more than an outright buy. There was much political resistance to this strategy and with the conviction of senior Air Force and Boeing personnel over serious ethics violations, the FY 2005 Defense Authorization Act terminated the previously-granted leasing authority.

Currently, there are two viable, commercially-available options that would be suitable replacement tankers—the Boeing KC-767 and the Northrop Grumman and EADS KC-30. Both tankers are based on commercial airframes; the technology being used is dual-use; the only additional development that may be required is for a unique refueling modification (both aircraft have already been modified and qualified as tankers, and have been bought by several countries). Consequently, this case is different from most Air Force aircraft development programs, since the Air Force can leverage the extant commercial production.

When developing an acquisition dual-source strategy for a complex, high-technology weapon system such as the tanker replacement, the government should strive to get more than just the cheapest system. In fact, competition often provides other benefits such as higher quality, greater reliability, improved innovation, and an enhanced industrial base. However, competition can introduce costs as well. In the case of the tanker replacement, the costs--that include the qualification of a second source, added non-recurring costs, the perception that it requires extra government management effort, and logistics considerations for two sources--should be minimal (as discussed herein). And, since we anticipate that competitive dual-sourcing will result in all the listed benefits, we believe that this strategy will result in a better value for the DoD.

Finally, based on a series of assumptions, we developed four competitive scenarios:

1. Winner-take-all. The winning bidder is awarded a contract to produce all 100 aircraft.

2. Directed split-buy. DoD directs a split-buy and both contractors are selected to produce a fixed percentage of the required aircraft (without further competition).

3. Competitive dual-sourcing with similar bids. Since there is not a significant difference in the bids (or "adjusted bids" if the performance or reliability are different) the production is split 50:50 between the two contractors.

4. Competitive dual-sourcing with significantly different bids. With significantly different bids (actual or "adjusted"), the lower bidder would produce 75 percent of aircraft, while the higher cost bidder would produce the remaining 25 percent. (Of course, the split could be adjusted, e.g. 60:40, but the extreme would probably be the 75:25 to assure the minimum buy for the "loser.")

Our analysis (using the cost growth factors from DoD sole-source programs and competitive commercial aircraft programs) shows that, in terms of cost saving, the last two scenarios—competitive dual-sourcing approaches—are strongly preferred to the first two scenarios, where there are no competitions during production. See the table below for a summary of the results.

	Optimistic	**Average**	**Worst Case**
Scenarios 1&2 Total A/C procurement	**$12B**	**$18.25B**	**$25.5B**
Scenario 3 Total A/C procurement	**$9.13B**	**$10.5B**	**$12.25B**
Scenario 4 Total A/C procurement	**$9.35B**	**$10.76B**	**$12.56B**

We conclude that maintaining two production sources for the replacement tanker is a feasible and desirable choice. Competitive dual-sourcing, not only generates cost savings and reduces operational risk, but also incentivizes innovation, improves the industrial base and the product quality, and provides a better overall value to the government from the procurement. The directed split-buy, however, bears all of the costs of dual sourcing, but virtually none of the competitive benefits. Since the replacement tanker is a modification of a commercial aircraft rather than a new development, it does not require a long design phase. Further, the logistic impact of maintaining two different aircraft is minimal, considering the current worldwide availability of servicing of both aircraft, and the net savings would be over $7 billion. Therefore, the costs of dual sourcing can be mitigated.

Findings

Our principal findings are:

1. Maintaining competition throughout a weapon system's procurement process, to include production, has many benefits. During production, competition creates incentives to increase "learning" for both the original and second producers.

2. The defense market is generally very different from the commercial market. And, based on consolidations in the defense industry, there are only a handful of contractors capable of developing and producing aircraft for the U.S. military. Consequently, even though the DoD is a monopsony buyer, competition is necessary to balance the power of the oligopoly suppliers.

3. The aircraft industry is becoming increasingly globalized. With the consolidation of the defense industry, multinational partners may be necessary to maintain both competitive pressure and the industrial base.

4. Dual-sourcing the replacement tanker acquisition has numerous advantages, as long as the commercial production is in place. First, the creation and maintenance of a competitive market that will significantly reduce the overall program cost.

Second, it incentivizes innovation, encourages product quality, improves the industrial base, and helps to provide a better overall value from the procurement. Finally, in the tanker case, dual-sourcing can also reduce operational risk by introducing a degree of resilience in the production and operation of the air-refueling fleet.

5. The directed split-buy bears all of the costs of dual sourcing, due to the higher non-recurring costs of two contractors and the smaller lot sizes, but virtually none of the competitive benefits. As a result, the program costs could actually exceed those of the single, sole-source program.

6. There are several negative costs, but they are generally mitigated by the fact the replacement tanker is a modification of a commercial aircraft. This effectively means that the tanker is not a new development, with a long design phase. It also means that the government can leverage the extant production sources, eliminating the cost of qualifying a second source, and, also, minimizing a significant share of the non-recurring cost of developing and maintaining two production facilities. Finally, since both aircraft are already in worldwide service, the logistics impact of maintaining two different aircraft should be minimal; especially if the (DoD-preferred), performance-based-logistics solutions are used.

Our objective with this study was to explore the benefits of dual-sourcing through production in general, and in the tanker program specifically. Our analysis shows that maintaining two production sources for the replacement tanker is feasible; and, in fact, highly desirable. Additional study, however, should be done to determine the optimal frequency for the production competitions and the lot sizes.

I. Introduction

A. Overview of Issue

The acquisition of air refueling tankers to replace the Air Force's aging fleet of KC-135's is one of the most important procurement decisions currently facing the Department of Defense (DoD). Since more than 60 percent of U.S. forward bases and en-route refueling bases have been closed over the past few years, aerial refueling is a critical enabler of U.S. power projections. Aerial refueling makes the rapid deployment of forces in response to contingencies possible, and then significantly increases airpower employment options. In addition, aerial refueling capability is still critical to the bomber leg of the U.S. nuclear forces, as well as other strategic missions, such as the airborne command post.

The current Air Force fleet has approximately 600 tankers, of which, 531 tankers are Boeing KC-135, and 59 tankers 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 beyond 44 years old, almost twice as old as the KC-10 (about 20years old).

Modernizing or replacing the current aging 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 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 developed a strategy to lease 100 Boeing KC-767 aircraft, approved by DoD, to replace the oldest KC-135Es, but this proposal caused a significant controversy. Critics argued that the proposed acquisition process was questionable and would considerably weaken congressional oversight. Congress also expressed its concerns about potential tanker options, industrial base, and the roles and missions of the aerial refueling fleet. Finally, when a major procurement ethics scandal involving the Air Force and Boeing was exposed, the lease option was removed from consideration.

In addition to recapitalizing a capability that is essential to the new expeditionary posture of the U.S. Air Force, tanker acquisition poses several interesting questions for the acquisition of a major weapon system in the new consolidated and globalized 21st century defense industry. These include:

- How does competition impact weapon system acquisition and what form should it take (e.g. for an award, or during implementation)?
- Are the benefits of continuous competition derived from dual sourcing greater than the costs of developing and maintaining the dual capability?
- How does the globalized defense industry affect the U.S. industrial base?
- What role should the government play in the natural evolution of the industrial structure and capabilities?
- Is dual-sourcing the tanker replacement a reasonable option?

The objective of this report is to address the issue of tanker acquisition and provide some insight into the above questions.

B. Organization of the Report

Section I of this report provides a brief overview of the issue and the organization of the report. The second section of the report begins by looking at the structure and characteristics of defense markets, and compares the defense markets with commercial markets. Then the historic impact and benefits of competition on weapon system acquisition are examined. The second section closes by studying the prevalent industry structure and examining the reasons why the government rarely uses its monopsony power in the oligopolistic defense supplier market.

The third section examines competition through a prism of cases that include the classic "Great Engine War," the Tomahawk experience, and the current Joint Strike Fighter (JSF) program.

Section IV looks at tanker aircraft specifically, a brief background of the acquisition process to date, and the nature of the dual-use technology and commercial market. In exploring other cost-benefit impacts, we explore how competition impacts personnel decisions, innovation, the industrial base, requalification, and logistics.

The fifth section analyzes the tanker strategy based on several assumptions. It provides four scenarios, with or without competition, and then compares the program costs under each scenario. The final section presents our findings and conclusions.

In summary, with this report, the Center for Public Policy and Private Enterprise (CPPPE) has aimed to explore, identify, and analyze opportunities, cost-benefits, issues, and options for choosing a specific sourcing program. Particularly, the CPPPE has made an effort to study competition and its effects on innovation and the industrial base, at the same time assessing implications of these factors on the overall cost of the tanker program.

II. Competition and Market Structure in DoD Acquisition

Competition is the driving force in the American economy. It has been found to inspire organizations, to drive innovation, improve quality, reduce costs, and focus on customers' needs.[1] Competition offers these same benefits to DoD, and has been the bedrock of federal and DoD acquisition policy. However, ensuring that the military has access to cutting edge technology, while maintaining a competitive environment, has proved challenging in the 21st century industrial and budgetary environment that the Department now faces.

The end of the Cold War and the accompanying reduction in the demand for military hardware were followed by a major restructuring of the defense industry, beginning in the early 1990s. Large, diversified companies, such as General Electric, Westinghouse, and IBM, sold off most of their defense holdings, and in large measure left the defense field. The remaining defense firms merged with their competitors in an attempt to reduce the remaining capacity and workforce. DoD viewed the consolidation as necessary in the new era of rapid technological change, smaller production runs, and fewer new starts. However, this trend slowed when the proposed acquisition of Northrop-Grumman by Lockheed-Martin was halted after the Justice Department filed an antitrust suit in 1998; DoD believed that the consolidation had gone far enough and that allowing this merger would stifle competition for military contracts. Today, only a handful of large defense prime contractors remain to supply the military's needs (see Figure 1).

[1] In technologically dynamic industries, competition has been described as having both a rivalry effect and a portfolio effect. The rivalry effect refers to the impact that the threat of oneself being displaced, or the prospect of displacing rivals, has on suppliers' incentives to perform. The portfolio effect refers to the impact the concurrent conduct of a range of independent development efforts has on the probability of identifying, in a timely and cost effective way, the optimal approach: with many horses in the race, the likelihood that one will be a winner rises. The extent of these effects and the net benefits that flow from them, depend on both the degree and type of competition (Argote 1990).

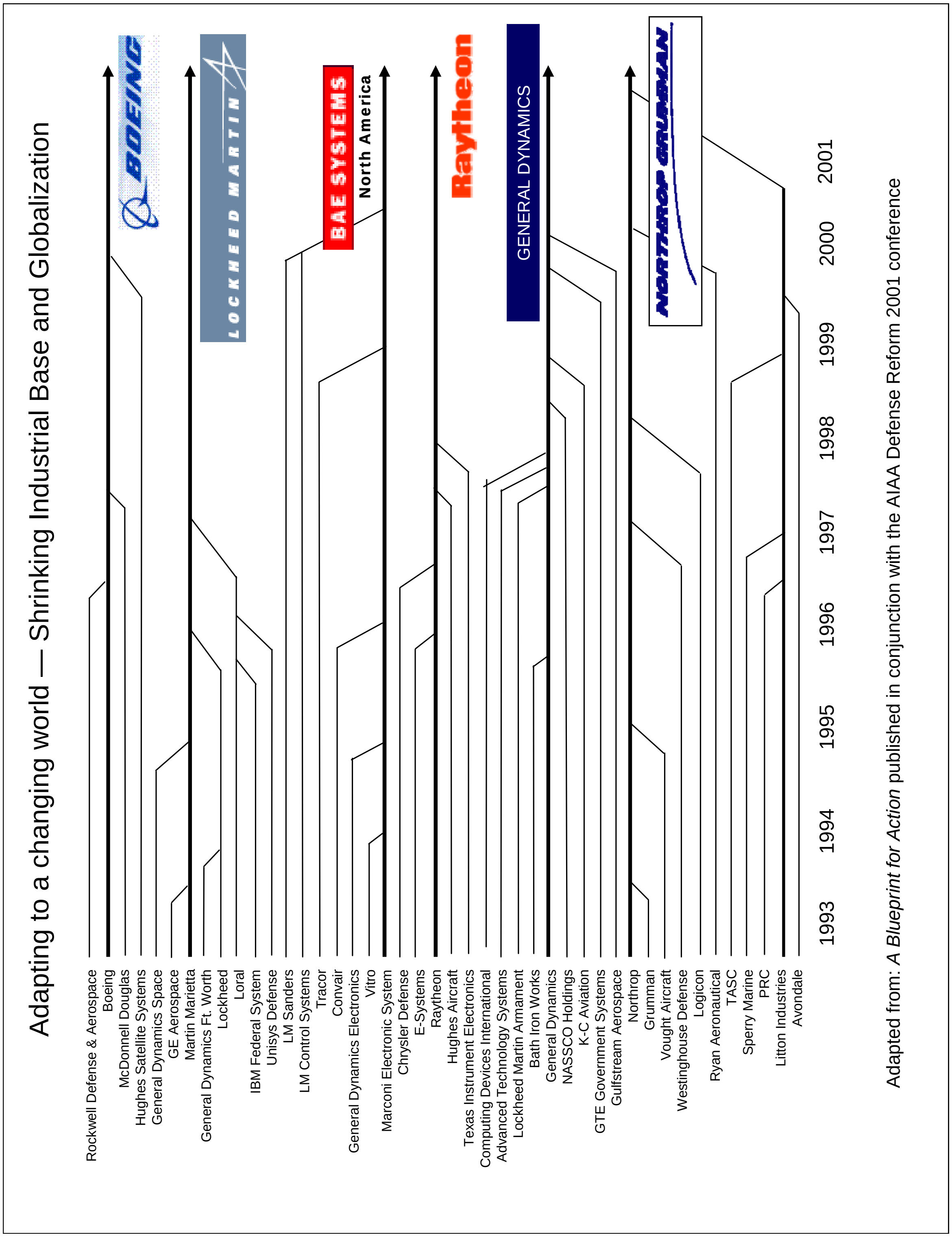

Figure 1. Defense Industry Consolidation

Although there is a possibility of using foreign entry as a means of fostering the competition in the defense industry, in particular the entry of European firms into the US markets, the reaction has been mixed. On the one hand, foreign entry is viewed as valuable, since it would stimulate competition and innovation while driving costs down. On the other hand, there are export control, technology transfer, and "buy American" issues. These latter concerns generally prevail, and foreign entry, on a systematic basis, is usually limited.

A. Theory of Markets

The long-established U.S. national security strategy has been to rely on superior technical capability, rather than quantity of military systems. In other words, the goal is for the U.S. military to always have weapon systems superior to any possible opponents. With the emphasis on research and cutting edge technology and a host of other constraints, Defense procurement has evolved with a set of rules and barriers that differ significantly from the classic, free-market model. A comparison with the economist's free-market model can best contrast the unique nature of the defense environment.

1. Commercial Markets vs. Defense Markets

Economists use the term "perfect competition" to describe a hypothetical market form often used to model the behavior of commercial markets. With "perfect competition," neither producers nor consumers have the market power to influence prices. This model is based on several assumptions. First, there are many competing buyers and sellers, so their individual actions have no impact on the market, and the firms have to take the price offered by the market. Second, both firms and consumers have perfect information. Third, the goods and services are homogenous and are perfect substitutes. Fourth, on the supply side, all firms have equal access to production technologies. Finally, firms are free to enter and exit the market. Economists describe the results of "perfect competition" as being "Pareto efficient," meaning that there is no market allocation that will make one entity better off without another being made worse off.

Additionally, when contrasted with other market forms, such as monopoly[2] and oligopoly[3], a firm in a perfectly competitive market generally does not make excessive profits. If it does in the short run, more firms enter the market, and drive down the price until all firms earn normal profits[4]. This theoretical model is, however, a distant approximation of reality, since few of these assumptions hold true in most real-world cases. This is especially true when considering the acquisition of major DoD weapon systems, and the defense industry in general.

In broad terms, DoD is involved with purchasing two major categories of items each year—(1) DoD unique parts, equipment, and systems, and (2) commercial supplies, parts, and equipment. The weapon systems that DoD procures are generally very high tech, purchased in small quantities, and at a high unit cost. The commercial market, on the other hand, procures items with proven technology, generally in large quantities, and at a low unit cost. Understanding the differences between the defense weapon system market and the commercial market is a necessary first step in developing acquisition policies and strategies. A contrast of the free market conditions and those found in the defense industry are presented in Table 1. However, since not all of the conditions of a perfect market can be met, removing some obstacles and moving toward the conditions of a free market alone, generally may not improve efficiency; policy analysis must keep the theory of second best in mind.[5]

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[2] A monopoly is defined as a persistent market situation where there is only one provider of a kind of product or service.

[3] An oligopoly is the market form in which a market is dominated by a small number of sellers.

[4] Normal profit is based on the opportunity cost of labor and capital, while supernormal profit exceeds the normal return.

[5] The absence of "perfect competition" does not, however, negate all economic theory. At the general level, the economic "theory of the second best" must be used for analyzing the desired market characteristics and policy options. This theory, formalized by Lipsey and Lancaster, states that if one optimality condition in an economic model cannot be satisfied, then an optimum situation can only be achieved by departing from all the other previous optimum conditions. Therefore, achieving more of the optimality conditions, is not likely to be superior to a situation in which fewer are achieved (Lipsey 1956).

Aspect	Commercial	Defense
Products	Proven Technology; rapidly applied	Cutting Edge Technology; slowly applied
Market Structure	Many buyers and multiple producers	One buyer, large items bought in small quantities
■ Demand	Competitive, sensitive to price and quality	Monopsonistic, rarely price sensitive driven by maximum performance
■ Supply	Competitive, adjusts to demand	Oligopolistic, large excess capacity
■ Entry and Exit	Movement in and out of market	Extensive barriers to entry and exit (e.g. unique DoD "requirements," perception of higher-cost of two suppliers, Congress)
Prices	Constrained by market competition	Cost-based and regulated
Outputs	Constrained by market competition	Determined by government
Risk	Borne by firm	Shared between firm and government
Profits	Constrained by market competition	Regulated by the government
Competition	In production	For R&D

Table 1. Commercial Markets vs. Defense Markets

There are three other characteristics distinctive in the U.S defense market. First, the government owns a significant amount of the plant space and equipment used by defense contractors (almost one third in the aircraft industry). For example, Air Force Plant (AFP) 42 is a major government-owned, contractor-operated (GOCO) facility located in Palmdale, California. AFP 42 has over 3 million square feet of industrial space. Boeing's employees at AFP 42 work on programs such as the X-37 and the Airborne Laser program. Northrop-Grumman employees at AFP 42 assemble the Global Hawk unmanned reconnaissance vehicle, and a major section of the Lockheed Martin F-35 Joint

Strike Fighter, as well as operate the airframe depot maintenance facility for the B-2 bomber.

The second area worth highlighting is that the barriers to enter in the defense market are extremely high. In addition to the entry barriers faced by any firm entering a new market, such as the cost advantage of the incumbents, the capital requirements, technology, and the number of competitors, firms entering the defense business face additional unique barriers. These include the required knowledge of federal acquisition regulations, specialized accounting and reporting requirements, the need for security clearances, and the ever-present political consideration.

Furthermore, Congress has passed numerous rules and regulations in an effort “to protect the government” from unqualified bidders who may arise in the case of “free and open” competition. Perversely, the excessive amount of regulation creates a significant barrier and greatly restricts the amount of effective competition (Gansler 1989). There are also significant barriers to exit, including specialized capital equipment, high overhead cost, and government sponsorship of defense-unique research; these make it difficult for defense firms to diversify into civilian markets.

Finally, DoD faces some real challenges when developing a cost-benefit framework for the evaluation of a weapon system’s acquisition. DoD leadership not only needs to factor in the cost of the program and its associated procurement option, the risks of that option, and the benefits of that option in relation to national military-strategic objectives; but must also consider the benefits to wider social, economic, and industrial objectives. Information on these wider benefits, such as impact on small and disadvantaged business, technology spin-offs, maintenance of the industrial base, are often based on qualitative judgments and can be especially difficult to convert into dollar amounts. Finally, there are also many political considerations, along with the support from many, often competing, interests.

2. Dual-Use Products

In the mid-1990s, the DoD recognized that rapid advances in commercial technology, combined with declining defense budgets rendered the traditional approaches to technology development and procurement less affordable and less effective. As a result, DoD implemented a strategy that emphasized the development and use of dual-use technology, as a way to allow the military to exploit the rapid rate of product development and the market-driven efficiencies of commercial industry to meet military needs. Dual-use technologies, products, and production capabilities can satisfy both military and commercial requirements at the same time. By leveraging the rapid commercial product development cycles, wherever possible, the military can shorten weapon system development time, increase the pace at which technological improvements are incorporated into new military systems, reduce the costs for procuring leading-edge technology, and help maintain the industrial capacity to meet surge requirements.

There was also an expectation that the aggressive transfer of defense technologies to commercial applications could ameliorate the effects of the defense industry downsizing in the mid-1990s. Firms could get economies of scale and also diversify their risks by evening out the business cycles in the separate markets, further leverage funding and capital investments while hedging against defense cuts.

> "An increased overlap between defense and commercial production is also seen to be desirable to maintain an adequate industrial defense capacity, improve efficiency in the defense sector, and allow for technological spillovers between the commercial and defense spheres."
>
> National Economic Council, Office of Science and Technology Assessment, 1995

However, the benefits of the increased use of dual-use technologies to the DoD do not come without costs to the commercial firms. In many cases, these firms must adopt DoD mandated accounting requirements, specifications and standards, and unique contract requirements; these are often cited as major disincentives. Firms producing dual-use products must also deal with the highly sensitive issue of technology transfer—once technologies are transferred to private companies for civilian use, there is a greater possibility that they will be exported.

Notable examples of dual-use products and production lines are information technologies (IT), Global Positioning Systems (GPS) used for navigation, jet aircraft engines, and most medical and safety equipment used by the Department of Defense. Modified commercial equipment like the Air Force's KC-10 tanker (McDonnell-Douglas DC-10) and the Army's light cargo vehicle, the Commercial Utility Cargo Vehicle (CUCV)—a Chevy Blazer—are also considered dual-use.

A classic dual-use aviation example was when Boeing used concepts and components from military aircraft (B-47 and B-52), including the J-57 jet engines and wing designs, to develop a civilian prototype aircraft, the Boeing 367-80. The 367-80 then provided the foundation for both the Boeing 707 passenger jet and the KC-135 military tanker aircraft. Much larger, faster, and smoother than the propeller airplanes it was replacing, it quickly changed the face of international travel and versions still serve as Air Force tankers.

For many applications, the DoD imposes more stringent standards for testing, quality control, and production even when the technology is the same. In the case of aircraft however, a recent RAND study concluded that “firms that produced exclusively for aerospace indicated using the same production processes for products manufactured or assembled for aerospace defense or commercial applications. These [survey] respondents stressed that there were no real differences in the product requirements —precision, testing, and quality control—required by these two markets. They used the same machinery and assembly processes.” Further, all firms in RAND’s sample “adjusted their accounting, testing, quality control, and production processes to meet the requirements of the defense and commercial markets with the attitude that it was a given, i.e., part of doing business" (RAND Institute 1996).

In summary, dual-use technologies are actively encouraged by the DoD. This policy not only provides extensive cost advantages but also allows multiple benefits across both the commercial and defense sectors. Further, the benefits accrue on both the supply and demand side of civilian and defense markets. Since both potential competitors have developed their proposed options based on civilian passenger aircraft, the follow-on to the KC-135 tanker will benefit from the use of a dual-use product.

B. Competition in Weapons Acquisition

The DoD strives to maintain a competitive environment in its weapon acquisition program. The competition for a major weapon system is, however, very different than experienced in most civilian markets. In the civilian automobile market for example, when one car manufacturer doubles the price of their vehicles, consumers can switch and buy other similar vehicles. In the defense market however, if a supplier significantly raises the price of a particular weapon system, DoD usually has little choice except to attempt to negotiate the price down.

Even though the competition is generally fierce for the initial award of the development of a weapon system; once that award is made, the weapon system is generally developed, produced, and supported by a single firm—a relationship that frequently lasts for many years (often decades). The subsequent absence of a buyer's alternative in the defense market creates a sole source environment; this alone makes a critical difference in the defense market.

This lack of competition, however, has generally not led to any collusion among the suppliers. Reasons for this lack of collusion are many (Gansler 1989):

- There is intensive oversight and high visibility;

- The government is a monopsony buyer, and as long as there is more than one supplier, the government can play the firms against each other;
- The government can bring in other firms or even enter the market itself;
- The demand is generally unpredictable, and lumpy in nature;
- Awards for major systems are infrequent;
- The "custom designed" products are non-substitutable;
- Competition is based more on technology that changes rapidly, and not price.

Another unique feature of the DoD's weapon acquisition process is that it involves several distinct phases – concept refinement, technology development, system development and demonstration, production and deployment, and operations and support (USD (AT&L) 2003). As a result, there are a large number of sequential decisions and contract negotiations that take place between the DoD and the prime contractor during the course of an acquisition. These decisions and negotiations result from the long program durations, DoD's institutional preference for short-term sequential decisions (including funding decisions), and the changes to product requirements and specifications over time. Commercial markets, on the other hand, typically have a more simplified and continuous transaction process.

Because competition is or can be used during the various stages of weapon system acquisitions, it is important to understand these differences.

1. Compete for Development

The weapon acquisition program begins by several contractors and thousands of researchers involved in small dollar value projects for research, technology, and exploratory development. This generic activity continues through the evaluation of subsystems in prototype demonstrations. The weapon program itself does not begin until the program definition phase is reached. Here, multiple contractors are usually funded to take the advanced technology and match it to a military mission. There is often a vigorous competition for the design stage, which can take three to eight years. Since these development contract decisions are subjected to enormous political and public scrutiny, DoD may need at least six months to make an award decision. The contracts are generally awarded to the contractor who promises the most capability and offers the least price. This stage ends when DoD selects a preferred design or designs and makes the decision to build a prototypes of the weapon (Gansler 1989).

2. Development Competition

Even though competition for development is completed (i.e. a "down selection" is made), there is an opportunity to maintain competition during the development phase. Although dollar values are still small, the commitments are firmer. Based on the expense, the number of competitive contractors for advanced weapon systems is normally limited to two. This stage typically takes from two to seven years (Gansler 1989). In many cases, however, the selected design is awarded sole source to a single contractor. The selected developer therefore, faces no competition during this phase, although the government always retains that option.

Based on the cost of new weapon systems and current acquisition policy, early competition in the system lifecycle is very desirable. By sponsoring the concurrent development of two or more competing weapon systems or key subsystems, which represent potential substitutes for filling a presumed military need, the government can hedge against uncertainties. This reduces the risk of being committed to an unsatisfactory approach and increases the probability of obtaining an acceptable end product (Scherer 1964). Additionally, competition during development results in less expensive, technologically innovative, and better integrated systems. This generally leads to earlier system maturity dates and significant life-cycle savings.

The Joint Direct Attack Munition (JDAM) example is frequently used to bring out the gains from competition in this stage. Two prime contractors competed and developed a system with reductions in time (33 percent development), cost (42 percent development) and price (42 percent per unit) (Myers 2002).

3. Compete for Production

After the development is complete, DoD can move to production of the weapon system. If there has only been a single contractor during the development phase, the production contract is generally negotiated in a sole-source environment; otherwise, a second source must to be qualified. If there are two systems developed, then assuming they both meet the mission requirements, DoD can compete the two contractors for the production effort. In the end, if production is initiated with only one source, the competitive pressure is removed.

4. Competition in Production

There is a natural tension when using competition during production between the relative benefits of a single-source award, to gain the benefits of learning/experience and the economies of scale, versus the benefits of competition. The learning curve effect expresses the relationship between experience and efficiency. The underlying premise is that as individuals and/or organizations become more experienced at a task, they usually become more efficient at it as well.

Second sourcing during the production stage is often perceived to be costlier due to various reasons, such as high technology-transfer costs. However, in the case of the tanker aircraft, as we discuss in the later sections, the tanker is not a completely new development – both sellers have modified (or are modifying) current commercial aircraft. Additionally both firms have sold these aircraft modified as tankers. There is a minimal requirement for technology transfer, and the normal development phase will have far lower costs than would be the case in a more traditional weapon system. Additionally, the use of the second source would ensure that the prices charged from the buyer are not monopolistic.

C. Benefits of Competition in Production

Learning curve theory would suggest that the total cost of an item will be minimized, with all other things being equal, if one procures that item from a single manufacturer.

However, all other things are rarely equal. Additionally, one of the fundamental premises of the learning curve is that the producer is attempting to increase returns (i.e. reduce the cost of production) in a competitive market. Therefore, when learning curves are employed to project the cost of sole-sourced productions, the projected learning is rarely achieved, since it is the presence of a competitive market that causes a producer to continuously strive for greater and greater efficiencies.

The Learning Curve Effect

The relationship between experience and efficiency is expressed by the learning curve. The relationship is direct, as a firm becomes more experienced, it becomes more efficient. The earliest use of the learning curve was in 1936, in an article published by T.P Wright; it described a basic theory for obtaining cost estimates based on repetitive operations during aircraft production. The basic idea is that the direct labor man-hours will decrease by a fixed percentage every time the production quantity is doubled. NASA calculates the learning curve for the aerospace industry at 85 percent; every time production quantities are doubled, the time (or cost) is reduced by 15 percent (NASA 2005 #79).

However, in the defense industry, selected single-source suppliers operate without competition and have very little incentive to reduce costs. Hence, observed learning curves in such cases reflect more the negotiation between a monopsony[6] buyer and single seller than real costs reductions by the contractor. Additionally, DoD sole-source contracts (even if “fixed price”) are often based on historical costs, and frequently create a perverse incentive for the contractor to increase rather than to reduce costs. For this reason, in the defense environment, sole-source learning curves have rarely been steep; and, in many cases, the total program costs have shown significant increases.

Learning curve theory, if applicable, would also suggest that when single-source production contracts are re-competed the original manufacturer would win the largest share of re-competitions (they would be further down the learning curve). In fact, (by contrast) historical data (1964-1979) show that re-competitions during production result

[6] A monopsony is defined as market for where there is only one buyer, a monopsonist.

in significant price savings—ranging from 12 percent to 52 percent (see Table 2). Thus competition can be viewed as “breaking the curve,” as indicated in Figure 2 (Defense Science Board 1996).

A more recent analysis that examined the effects of competition on 14 tactical missile programs, over the period of 1975 -1995, reaffirmed these results. It was concluded that dual-sourcing production produced net savings on the order of 20 percent (even after considering the added costs of two sources and the reduced quantities of both suppliers). In addition to the cost savings, dual-sourcing 1) increased the availability of supplier information between competitive suppliers that resulted in more aggressive bidding; and 2) gave the government more leverage on non-contactable issues of quality (Lyon 2006).

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%

Table 2. Benefits Shown in Earlier In-Production Competition Studies

In cases where there has been continuous competition during production in U.S. tactical missile programs, the results have shown that the second source actually achieves a steeper learning curve (see Table 3)—ranging from 2 percent to 9 percent more learning (Defense Science Board 1996).

Program	Cost Improvement Rate		Percent Difference
	First Source	Second Source	
AIM-7F	0.87	0.84	3.00%
BULLPUP	0.82	0.80	2.00%
TOW	0.98	0.89	9.00%
AIM-9L	0.90	0.83	7.00%
AIM -9M	0.94	0.85	9.00%
HELLFIRE	0.94	0.92	2.00%
TOMAHAWK	0.79	0.71	8.00%

Table 3. Impact of Production Competition on Learning (Defense Science Board 1996)

This in turn exerts price pressure on the original producer, producing an immediate shift downward, with a steepening or "rotation" of the learning curve (see Figure 2). These price reactions by the initial producers allow them to remain competitive. As a consequence, competition has been shown to drive both producers to greater efficiency than previously demonstrated by the single source.

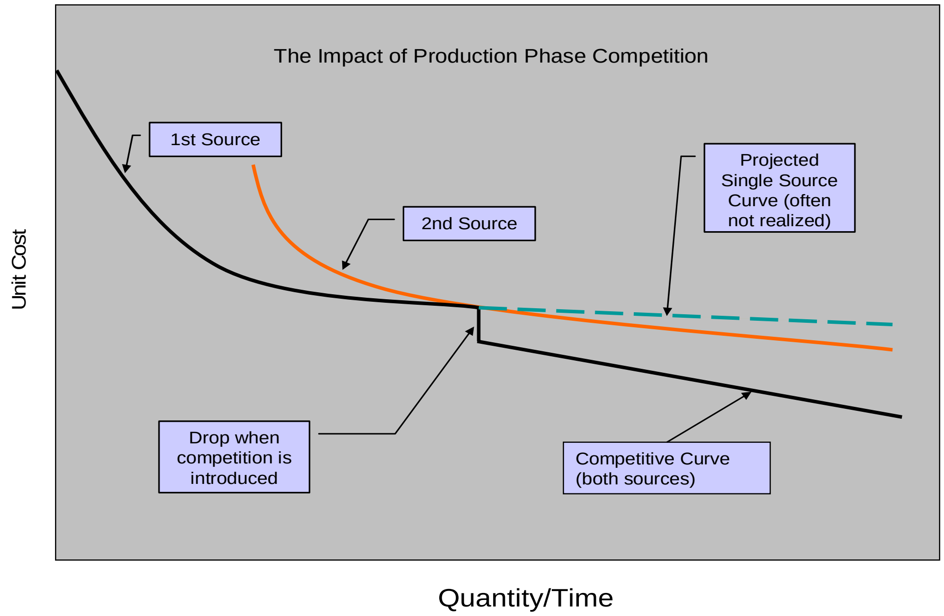

Figure 2. Initial Source Reactions to Competition During Production (Defense Science Board 1996)

One can also consider how competition affects the cost growth of programs. For this effort, we examined two sets of data: Cost-Growth factors for non –competitive DoD aircraft programs (see Table 4) and Cost-Growth factors for commercial aircraft produced in a competitive environment (see Table 5). The Cost-Growth Factors on the DoD programs with no production competition, based on actual cost incurred vs. program baseline, increased by 46 percent, on average. Of the 10 programs studied, most showed an increase between 25 percent and 104 percent. Only two programs—A-6E/F and B-1B—presented a modest decrease.

Aircraft	**Cost-growth Factors**
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**

Table 4. Cost-Growth Factors for DoD Aircraft Programs with no Production Competition (John Birkler et al, 2001)

By contrast, cost-growth factors for commercial aircraft produced in a competitive environment showed a decrease between 2 percent and 27 percent, as indicated in Table 5. The Overall simple average was 16 percent decrease over program life (Historical Lease Rates/Values 1971-2000, http://www.aircreft-values.co.uk).

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

Table 5. Cost-Growth Factors for Commercial Aircraft Produced in a Competitive Environment

One other benefit of dual-source programs was identified in a 2001 Office of the Secretary of Defense Cost Analysis Improvement Group (CAIG) study. This study examined the cost growth of sole-source and dual-source programs based on program changes and technical problems which the CAIG identified as "mistakes." These mistakes included:

- Production quantity assumptions and estimation changes;
- Engineering, test, and development changes;
- Integrated Logistics Support (ILS) changes, and spares and support changes not attributable to post-milestone II discretionary decisions;
- Schedule slips attributable to technical problems;
- Other changes not attributable to discretionary changes.

As shown in the Table 6, the cost growth during Engineering and Manufacturing Development (EMD) of dual-source programs (AIM-9M, AMRAAM, HARM, Hellfire, Peacekeeper, and Tomahawk) is 7.4 percent, approximately one fourth that of non-dual-source programs which is 29.4 percent. The cost growth during procurement exhibits a similar pattern: 4.1 percent for dual-source programs vs. 15.2 percent for non dual-source programs.

	Dual-Source	Non Dual-Source
Number of Programs	6	19
Percent EMD Changes Cost Growth	7.4%	29.4%
Percent Procurement Changes Cost Growth	4.1%	15.2%

Table 6. Cost Growth in Dual-Source Programs vs. Sole-Source (OSD CAIG 2001)

In summary, the ever-present threat of losing business to a competitive producer is a most effective performance inducement that results in increased innovation, performance improvements, quality improvements, and net cost savings—better value for DoD and the U.S. taxpayers (see below for examples of performance improvements from competition e.g. in "the great engine war and the cruise missile cases).

D. The Defense Market: Monopsony Buyer & Oligopoly Suppliers

1. Why Government Uses Its Monopsony Power Sparingly

When buying major weapon systems or other unique defense equipment the federal government is easily classified as a monopsonist. As a monopsony buyer, the federal government determines whether defense industries are to be state-owned (as with arsenals and depots) or privately-owned. It can also use its buying power to determine the size of the nation's defense industries, ownership, entry, exit, structure, conduct, and performance. Additionally, the government can determine whether the defense market will be open, allowing foreign firms to bid on national defense contracts (making markets contestable), or whether its market will be closed, with preferential purchasing restricted to national firms. Similarly, government can support industrial restructuring and mergers through subsidy and/or purchasing policy, or "bail out" firms facing bankruptcy. Government affects industry conduct by determining the form of competition for weapons' contracts.

Although the government, as a monopsonist in the defense market, can theoretically wield significant power, in reality, for various reasons, it generally uses its monopsony power in a limited way. First, the federal government is not a single unitary decision maker. In practice, acquisition decision making is spread across several agencies, along with Congress. Within the DoD, there are the Services, with their rivalries, as well as the diversity of their many program officers. These program offices are often competing for budget share, resources, and distinct priorities not only among services, but also among elements of each service. Since these program offices in the different services are the true ”customers” of defense firms, the commonly assumed model of pure monopsony loses some of its descriptive power. These different power centers often make their own deals with Congress, even though most this practice has been actively discouraged by every recent Secretary of Defense. The reality of this diffused authority, along with the imperfectly coordinated bargaining and decision making, makes the existence of competing firms even more important since, otherwise, a single supplier would have more power to exploit differences among the many separate procurement offices (Kovacic 1994).

Second, although federal acquisition regulations provide acquisition officials with powerful tools to ensure contractors charge reasonable prices, provide quality goods and deliver them on time, contractors do retain an important measure of discretion to exploit superior information. And, as a result, they often can negotiate prices that are above competitive levels, or renegotiate existing contracts on terms that are more favorable. Federal regulation is an imperfect proxy for competition as a check against shirking or opportunism by entrenched sole-source suppliers, the government could derive significant additional benefits from preserving at least two additional competitive sources for each type of weapon system (Kovacic 1994).

Third, the inherent nature of many contradictory objectives makes it even more difficult to use government’s monopsony power. The acquisition process faces three challenges—the desire for higher performance at a lower cost, for innovation, and for competition. Additionally, there are social and political objectives, as well as the requirement to act “fairly.”

Finally, unless a competitive environment is maintained through production, the winning development contractor becomes a sole-source supplier, and develops an increasingly powerful position. With the passage of time, the government becomes more and more dependent upon this contractor, which is providing a required product. In addition to the cost involved, developing a substitute product could take up to ten years. “From this point on, the contractor is in a position to go to the government with ‘explanations’ of ‘government-introduced’ problems that are increasing costs, causing delivery delays, and so forth, and to bargain for increased prices” (Gansler 1989).

2. Oligopoly Power

The small number of sellers in the defense market forms an oligopoly, serving a monopsonist. In many cases, this oligopoly is designing innovative, new products, for which there is no production experience; and at prices for which there is little precedent. The funding for their programs can change unpredictably, and can even be canceled suddenly. Other factors outside the control of the government, such as technology, world conditions, defense strategies, threats and politics, can significantly influence the market. The high initial investments often make public financing difficult and can mean that their ultimate profitability might not be known for a decade. In many respects, this oligopoly faces an environment very different from the commercial marketplace.

A useful framework that can be used to evaluate the nature and degree of competition in an industry was developed by Michael Porter, a Harvard Business School Professor. Porter posited that there are five competitive forces that shape an industry. The five forces are: the threat of entry by new competitors, the bargaining power of buyers, the bargaining power of suppliers, the threat of substitute products, and the jockeying for position among existing competitors. We will use this framework to evaluate the military aircraft industry, focusing specifically on the commercially-based tanker aircraft.

The five forces model takes into account supply and demand; substitutes and complementary products; relationships between costs and volumes of production; and market structures like monopoly, oligopoly, and perfect competition. However, it does not take into account strategic alliances along a value chain, dynamic markets, and complex industries with multiple interrelations. At the same time, the value of Porter's analysis is that it enables a starting point analysis – allowing managers to think about their industries in a structured and easy to understand way. The diagram below (figure 3) is a handy way of depicting the five forces Porter identifies and providing some elaborating detail.

From the Porter analysis, we can see that the high barriers to entry, coupled with uncertain and risky outcomes, restrict market entry; and, therefore, some bargaining power shifts to the sellers. Additionally, since this is a national security issue and there is a low threat of substitutes, the government loses some of its purchasing power.

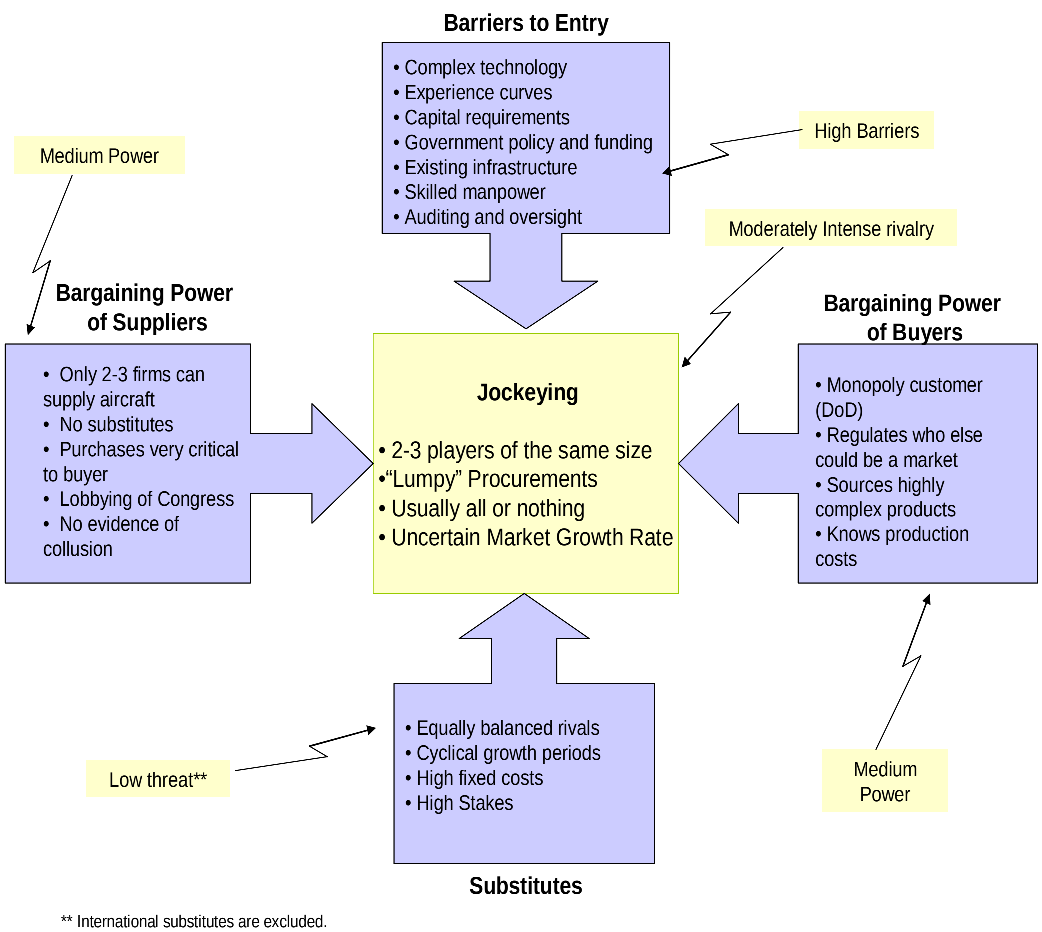

Figure 3. Analysis of the Defense Industry –Oligopoly Power (based on Porter's Model)

As a result, even though the government is a monopsony buyer, it only has medium power. Moreover, as long as there are two or more viable competitive suppliers, the government can balance their power.

III. Cases in DoD Acquisition

A. The Great Engine War

The Alternate Fighter Engine (AFE) program is a classic example of a DoD weapon system acquisition program in which competition was successfully applied during production.

One of the main reasons that the Air Force decided to introduce competition in the AFE program can be traced back to its relationship with Pratt & Whitney Aircraft (P&W). P&W had been the sole producer of Air Force jet fighter engines during the 1970s and early 1980s. The F-15, introduced in the mid-1970s, was designed and built around two P&W F100 engines and demonstrated the great performance that the Air Force wanted. However, toward the end of the 1970s, some durability and performance issues began to surface, and the Air Force's perception was that P&W was taking advantage of their monopoly situation and becoming complacent and non-responsive to Air Force needs.

At the operational level, the idea was to improve reliability and durability of engines, and reduce overall life cycle costs of the aircraft. This idea was derived from the continuing pain of the Air Force from the poor durability and high maintenance costs of the F-15 engines. These were caused primarily by the failures of the F100's fuel delivery system, the turbine problems, and performance problem identified as "stall stagnation." Stall stagnation occurred when a pilot suddenly called for full throttle at high altitude and low speed; under these conditions, the F100 engine had a propensity to stall while fuel continued to pour into its combustor. This problem could seriously damage the engine. The only way to avoid this damage was for the pilot to shut down and restart the engine in flight; this was unsafe during training and completely impractical procedure for wartime operations. The Air Force and P&W could not agree on who should pay to fix the problems, and the relationship between them deteriorated as the problems persisted with the F100 equipped fleet. Making the problem worse, in 1975 the Air Force selected the F-16, a single engine design using the F100 engine, as its next fighter. Now both of the Air Force's frontline fighters were dependent on the same engine. Meanwhile, there was an increasing concern within the Department of Defense about the sustainability of the industrial base.

The "winner-take-all" approach of these two procurements had excluded the other U.S. contractor, General Electric, from the Air Force fighter engine market. The company had used its own funds to develop a demonstrator engine, the F101X, with the idea of selling it to the Navy to re-engine its F-14 carrier fighters. While the Navy showed little interest in it, the Air Force offered GE a chance. The Air Force believed that the F101X could eliminate stall stagnations, significantly improve durability, and reduce operating costs. It regarded the F101X as a possible alternative to the F100, and the competition from GE as a potential threat to P&W might force P&W to perform better and cooperate with the Air Force more closely.

GE enthusiastically embraced the AFE competition as a great opportunity for them to get some of the Air Force fighter engine production business. Although P&W intensely resisted this threat to its monopoly position with the Air Force (including using all the political pressure it could) the Air Force continued its support for a GE competition. Both companies submitted their formal bids in 1983, in response to the Air Forces request for proposal. After the source selection that considered performance, prices, spares, and warranties of both bids (P&W's F100 and GE's F110), the Secretary of the Air Force made his award decision in February 1984. His decision was to split the production between the two companies: GE would build 75 percent (120 F110s) of the FY1985 buy of fighter aircraft engines, and P&W would build the remaining 25 percent (40 F100s). The F110s would be installed in the F-16 aircrafts while the F100s were for the F-15 aircrafts. This one-year award was scheduled to be reassessed for the succeeding years in a hope of continuing competition between these two companies.

The Great Engine War resulted in many benefits to the government. First, the competition vastly improved the reliability, maintainability, and durability of the fighter aircraft engines while providing better performance. Specifically, the shop-visit rate, per 1000 engine flight hours, was half the pre-competition engines. Additionally, the scheduled depot return increased from every 900 cycles to every 4000 cycles. Second, the competition forced the contractors to be more responsive, efficient, and effective, which benefited the contractors as well as the government. The competitive pressure forced P&W and GE to treat the Air Force more like their commercial customers, upgrade their manufacturing capability, and make other capital investments to reduce costs and improve quality.

The competition also significantly enhanced warranty coverage and lowered warranty costs, which further reduce government costs. Before the competition, the single source P&W had offered the service warranty at a cost of $53 million. The competitive bid by General Electric offered a significantly lower cost – a 5 percent premium. This counter by GE forced P&W to revise its first bid and negotiate a sum significantly below the $53 million. Other benefits included that the competition allowed dual lower-tier suppliers, enhanced operational flexibility, enlarged industrial base, and provided considerable protection from production disruption. Finally, the competition yielded between $2-3 billion in net savings (then-year dollars) in the twenty year life cycle costs of ownership, compared with continued sole-source procurement of the existing F100 engine.

The Air Force proclaimed the competition a great success. The Great Engine War also complied with the Competition in Contracting Act (CICA) of 1984 which recommended continuing competition on major weapon system acquisitions throughout program life cycles, including the production phase of a program. Several factors contributed to the success of the program. First, there was a low level of technological risk posed, since both F100 and F110 were derivative engines based on proven designs, i.e., they relied on existing technology which only required adjustments rather than a major overhaul. Second, there was no serious risk from outside the programs, such as the unexpected changes in policy or government funding which might have affected the support for the developments. Third, costs associated with establishing a second source were minimal since both engines had been developed. Fourth, competition was used to motivate the contractors. Especially, the warranty that accompanied the production contracts forced both contractors to honestly reveal their expectations about actual performance of their engines. Finally, the nature of the contracts—fixed price and warrantees—was employed to structure the competition.

As the Air Force Assistant Secretary said, the Great Engine War generated the "classical benefits of competition" and provided the "competitive leverage to drive the prices down" (Congress 1984).

B. The Tomahawk Experience

The Tomahawk experience is another good example of successful second-sourcing in the defense market. Tomahawk is a family of missiles with different launching modes and different missions. In 1977, the Navy established the Joint Cruise Missiles Project Office (JCMPO, or, today, CMP) to develop the air-launched cruise missile (ALCM) and ground-launched cruise missile (GLCM) for the Air Force and sea-launched cruise missile (SLCM) for the Navy. The GLCM and SLCM are also called Tomahawk. The program intended to achieve commonality among the different missiles by using a common engine and land-attack guidance systems.

Since the inception of the program, the CMP directed extensive use of dual-competitive sources for all major elements of the missiles. Companies participated in the competition included Williams International Corporation, Litton Guidance & Control Systems, Litton Systems Limited of Canada, General Dynamics/Convair Division (GD/C), and McDonnell Douglas (MDAC). The latter two companies were particularly involved with the production and integration of the Tomahawk family of missiles. The GD/C was the airframe producer and flight vehicle integrator while the MDAC produced and integrated the guidance system.

To improve system reliability during the development, the CMP wanted to shift a large degree of responsibility for production quality of the overall missile to the manufactures, but GD/C was reluctant to warrant MDAC-produced guidance systems. In 1982, CMP decided to force an exchange of technology between the two companies and dual-source the All-Up Round (AUR), a flight-worthy Tomahawk missile contained in a launch-compatible canister and capsule. Thus, the two companies had to reciprocally transfer all necessary technology and to negotiate the terms between themselves and the government. The related costs were recovered as a contract cost spread over the first 1,200 missiles produced by each company. Meanwhile, the government provided the two companies certain incentives to carry out the technology transfer effectively and quickly. Each company was guaranteed 30 percent of the annual buy, with the remaining 40 percent to be allocated depending on bid prices. The CMP awarded MDAC a directed buy of 36 airframes and 208 guidance sets, while gave GD/C 208 airframes and 36 guidance sets in FY 1985. However, the dual-source arrangement did not involve any direct investment by the government. The contractors were asked to fund technology-transfer costs and purchase tooling and test equipment by themselves.

The introduction of a second production source was expected to accrue benefits from the expanded industrial base and the warranty provisions. In addition, the government also expected that the AUR dual-source arrangement would drive down the AUR costs due to the fact that the two suppliers competed for the larger share of each annual buy. As Figure 4 shows, AUR unit price was slightly higher in the non-competitive, dual-source case in the third year of production, FY 1983; but dropped below the estimated single-source price in FY 1984, the first year of competition (as the CMP intended). The cost saving effect by FY 1988 was clearly visible. According to a 1989 Naval Center of Cost Analysis (NCA) estimate, Tomahawk competition up through FY 1994 will save $630 million in then-year dollars, $550 million in FY 1989 dollars, or $270 million in discounted FY 1989 dollars (Naval Center of Cost Analysis 1989)..

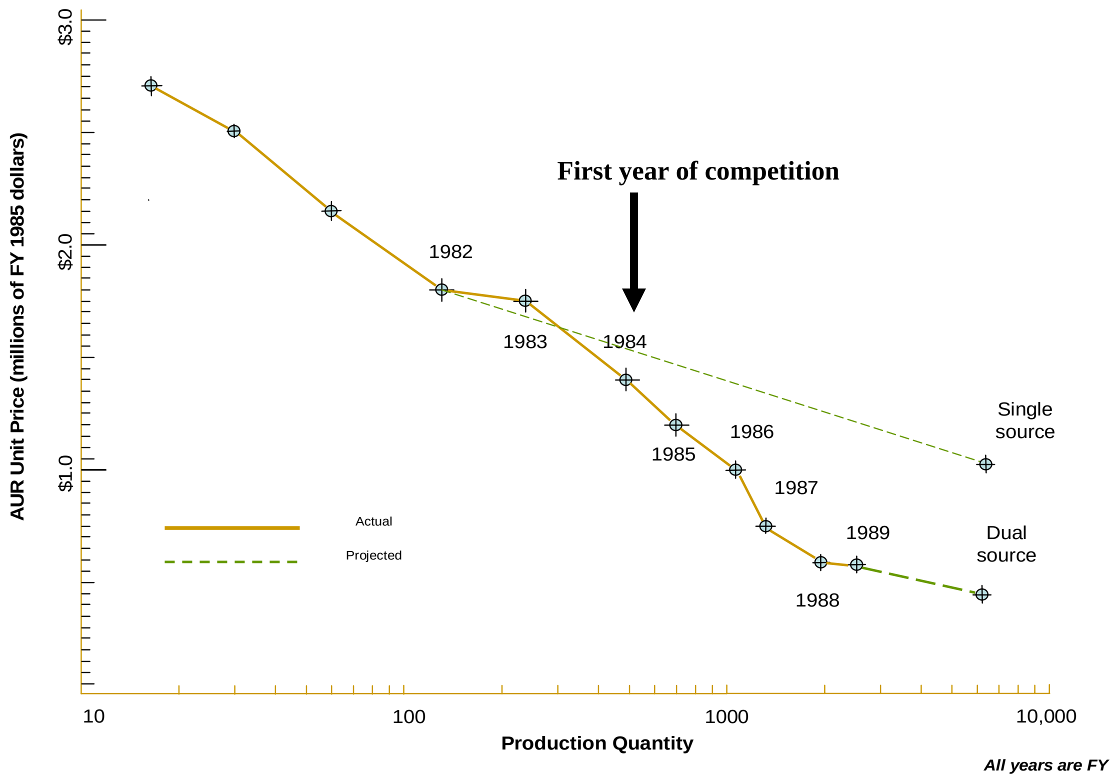

Figure 4. 1989 CMP Unit Price Comparison ((Birkler 2001)

One should be reminded that the primary reason for second-sourcing the Tomahawk was not to reduce cost but to improve system reliability. The CMP believed that dual-sources would provide an expanded mobilization base, a greater degree of AUR reliability, and an opportunity to negotiate production contracts in a competitive environment. The system reliability actually did improve from approximately 80 percent to 97 percent. This increase was largely attributed to CMP initiated corrective action as well as competitive pressure. The Defense Contract Administration Services Plant Representative Office (DCASPRO) issued five Method C corrective-action requests between November 1981 and May 1982, and a Method D corrective-action request in June 1982 to deal with what the CMP perceived as serious quality-assurance problems. Reliability showed a perceptible improvement by mid-1983, and overall missile reliability eventually achieved a level comparable to that of other missile programs. The

CMP, GD/C, and the Office of the Secretary of Defense/Program Analysis and Evaluation (OSD/PA&E) studies all concluded that dual-sourcing saved the government money after three years of competition while improving performance.

Several unique factors that are hardly seen in other major system acquisition programs played critical roles in the success of the Tomahawk program. First, the cost of entry for a second source during production was quite low—less than 2 percent of the projected production cost of more than 4,000 missiles. Second, the original airframe producer, GD/C, initially projected a relatively flat learning curve, 91.6 percent, in its own studies. Virtually every other missile program has achieved a steeper slop, and GD/C showed later, under the spur of competition, that greater price reductions were achievable. Third, annual production quantities have been large enough to absorb the fixed and semi-fixed costs without distorting AUR unit costs unduly. Last, but not least in importance, the CMP effectively managed the competition aspects of AUR procurement.

C. The Joint Strike Fighter

The Joint Strike Fighter (JSF) a joint multinational program for the U.S. Air Force, Navy, and Marine Corps, with full partnership participation by the United Kingdom, along with some participation from seven other international partners. The objective of the program is to develop and deploy a family of strike aircraft to satisfy the diverse needs of the three services of the US military, the UK, and other US allies. The program attempts to employ one basic design of high commonality (over 70 percent) in structure and subsystems, core engine, and mission systems (avionics) among multiple variants that include a conventional takeoff and landing (CTOL) variant, a short takeoff and vertical landing (STOVL) variant, and a carrier variant (CV). This high commonality is expected to reduce overall

acquisition and support costs, thus making the JSF more affordable during production and throughout the service life of the aircraft.

In 1996, the DoD used a compete-for-development strategy and selected the Boeing Company and Lockheed Martin as the JSF's two finalist prime contractors and intended to grant one of them the right to develop and produce all variants of the JSF in fall 2001—a production of more than 3,000 aircraft that is worth over $300 billion in then-year dollars.

As these two companies' efforts unfolded, the Secretary of the Air Force, James G. Roche, the official in charge of selecting the JSF winner, stated that Lockheed Martin's proposed aircraft and development program clearly offered "the best value for the government" across a range of competitive categories (Tirpak 2002). The JSF production was a winner-take-all decision, and the single source, Lockheed Martin Corporation, is likely to be the exclusive supplier of manned fighters to the U.S. military at the end of this decade.

This "winner-take-all" approach has been the typical strategy employed by DoD to acquire major weapon systems. However, some DoD officials were concerned that awarding the JSF to a single source would result in higher costs and less technologically innovation as compared to maintaining a robust competitive environment through the aircrafts production.

Congress was reluctant to concentrate all manned fighter work with a single contractor facing no competition and had questioned the single source development plan numerous times. In 2000, Congress asked the Pentagon three times to review the winner-take-all approach. Depending on the amount of production capability to be duplicated, it was estimated that setting up a second production line for the JSF would cost an additional amount between $1 billion and $4 billion. Congress was worried about losing skilled engineer knowledge in designing fighters, considered by some as a "perishable commodity."

Additionally, in 2000, the Under Secretary of Defense for Acquisition, Technology, and Logistics asked RAND Institute to explore the feasibility of introducing competition during the production phase of the JSF. The RAND analysis concluded that establishing a second production source would require a significant investment of non-recurring costs, which would not be fully recovered through the savings that would result from production competitions. Based on the analysis, RAND offered two policy recommendations. First, the program should stick with the winner-take-all strategy for near-term development and production of the JSF. Second, the JSF program should consider maintaining pressure at the subsystem level by supporting a second industry team to develop and produce the follow-on integrated mission equipment suite. This was based on the fact that a very significant portion of the aircraft cost was in the subsystems (engines and electronics); and approximately half of the electronics programs that RAND examined, with two or more production sources, achieved a 30 percent savings with competition (see Table 7) (Birkler 2001).[7] It was therefore decided to dual-source the engines and the major avionics elements. However, cost pressures on the DoD and the JSF led to initially sole-sourcing the avionics (with the option of introducing competition later) and, in 2004, the DoD (in a short-term "cost saving" budget action) decided to drop the engine second source.

Savings Achieved	**Electronics Programs**
>0 %	10/10
>10 %	9/10
>20 %	7/10
>30 %	5/10
>40 %	4/10

Table 7. Fraction of Programs Electronics Programs Examined that Achieved Savings (Birkler 2001)

[7] The DoD's decision to cancel the JSF alternative engine program came under significant criticism from the GAO (GAO-06-717R 2006) and some members of Congress.

IV. USAF Replacement Tanker Aircraft

A. The Background

As previously described, the U.S. Air Force's fleet of tankers is critical to the effectiveness of the U.S military. The current Air Force fleet of 531 of KC-135s, now average well over 40 years in age (see Table 8). The other tanker aircraft, the KC-10A, although newer, have been in service about 20 years on average.

	KC-135 E	KC-135 R	KC-135 T
Possessed Aircraft	102	301	45
Computed Average Age	46.8	44.2	46

Table 8. Computed Average Age of KC-135s

Aircraft life is measured in three ways: usage, age, and utility. Usage is defined by flight hours. In terms of flying hours, the KC-135 fleet's total flying hours are only approaching middle age, when compared to commercial standards. Using this standard, the fleet could fly until 2040, when the aircraft would be about 80 years old (Bolkcom 2005). Corrosion, on the other hand, is a function of physical age. Unfortunately, the KC-135 design, materials, and construction of the 1950s did not consider corrosion prevention measures. Additionally, stress corrosion cracking is difficult to predict, and requires frequent, comprehensive inspection--significantly reducing availability. Finally, utility refers to the ability to accomplish the intended mission in the current operational environment. As a consequence, aircraft must be routinely updated to reflect current technology to comply with current safety, environmental, and ATC standards; as well as to accomplish missions within the current joint warfighting framework, the need for self-defense, and be sustainable with available spares.

As the KC-135 fleet ages it requires more maintenance, reducing the number of aircraft available for operations. This has the effect of decreasing the KC-135 Fully Mission Capable (FMC) rate at about 2 percent per year. With newer tankers and their increased availability, the AF could replace KC-135 on a more favorable basis than one-for-one.

The expense and time required to maintain aging tankers are also increasing. Maintenance per possessed aircraft is growing at an annual compound growth rate 6.1 percent for KC-135E, 6.6 percent for KC-135R, and 13.4 percent for KC-135T. New tankers would require significantly less maintenance (Keating 2003).

Based on a RAND analysis, if 136 KC-135 tankers are replaced with 100 new tankers (RAND modeled the Boeing 767), the cost to operate the KC-135s (with a projected availability of 58 percent) would equal the annualized lifetime cost of the new tankers, when the average age of the KC-135 is 49 years old, or reached the year of 2008 (Keating 2003). See Figure 5 below.

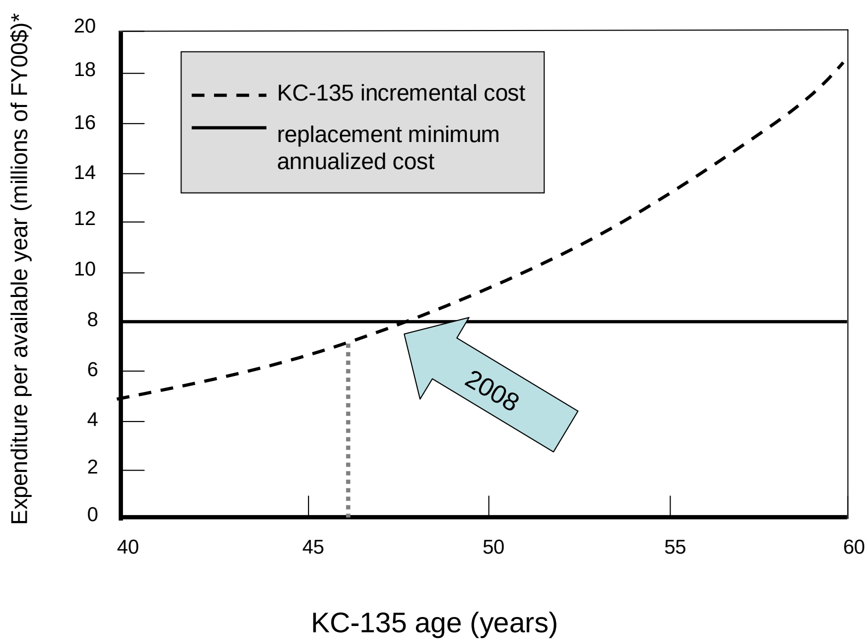

Figure 5. Projected Expenditure per Available-Aircraft Year (Keating 2003)

B. Previous Strategies

The U.S. Air Force has, in the recent past, explored a number of options for maintaining and improving the aging fleet. All of the active duty aircraft have been modified and designated KC-135R. These aircraft have been upgraded with the quieter, more fuel-efficient CFM56 engines. This engine is an advanced-technology, high-bypass turbofan, manufactured by CFM International, a company jointly owned by SNECMA of France and General Electric of the U.S. Related system improvements are incorporated to improve the modified airplane's ability to carry out its mission, while decreasing overall maintenance and operation costs. However, the operations and maintenance costs and time undergoing depot maintenance are expected to continue increasing, making many agree that the fleet needs to be modernized.

There was a controversy on the initial acquisition plan (Section 8159 of the FY 2002 DoD Appropriations Act) which authorized the Air Force to lease 100 Boeing 767 tankers. The cost of leasing was valued at $29.4 billion which was $4.4 billion more than an outright buy. Besides the cost, leasing arrangements are typically not suitable for long-term requirements, if the aircraft are highly specialized; and no private sector market exists. Studies by the Congressional Budget Office (CBO) and the Office of Management and Budget (OMB) reached similar conclusions. This, plus admitted and alleged ethical violations, added to the controversy. The FY 2004 Defense Authorization Act backtracked, and authorized the lease of no more than 20 aircraft and the purchase of 80 more. With the conviction of senior Air Force and Boeing personnel over serious ethics violations, the FY 2005 Defense Authorization Act terminated the previously-granted leasing authority.

C. Commercially-Developed Options

The options currently being evaluated involve some competition between the Boeing KC-767 and the Northrop Grumman and EADS KC-30.

Historically when firms win initial development contracts, they became the single source suppliers. One of the primary reasons for this is that there is no commercial market for that product. In this case, however, both tankers are based on commercial airframes; the technology being used is dual-use; the only additional development that may be required is for a unique refueling modification (both aircraft have already been modified and qualified as tankers, and have been bought by several countries). Consequently, this case is different from most Air Force aircraft development programs, and maintaining dual-sources of supply may be an effective option. A brief description of the two aircraft follows:

- The Boeing 767 tanker transport aircraft designated KC-767 for the US Air Force, is a high performance version of the 767-200ER twin aisle jetliner equipped for fully integrated tanker operations. It is fitted with a boom and receptacle refueling hose, and drogue refueling, or both.

  

  The configuration of a commercial 767 for the tanker transport role involves the installation of additional pumps and auxiliary fuel tanks together with the fuel distribution lines below the floor of the main cabin, leaving the main cabin free for cargo, passenger or both cargo and passenger transportation. The concept allows simultaneous refueling and airlift operations or successive refueling and airlift missions. In the cargo configuration, the aircraft can transport 19 standard military 463-L pallets; in the passenger configuration, 200 passengers can be accommodated; and in the combined configuration ten cargo pallets and 100 passengers can be carried(Air-Force Technology 2005).

- The KC-30 is derived from the Airbus 330 wide-body twin-engine passenger jet. It is equipped with a centerline flying boom - along with two under-wing hose & drogue pods and a fuselage hose and drogue refueling unit. The KC-30 can refuel multiple aircraft simultaneously, and is interoperable with U.S. Air Force, Navy, Marine Corps, and allied aircraft on the same mission.

EADS North America is a team mate and Principal contractor of the Northrop Grumman KC-30 industrial team. More than 50 percent of the aircraft, subsystems, and support will be provided by American partners and suppliers. Mobile, Alabama's Brookley Industrial Complex was selected as the site for the KC-30 advanced tanker U.S. production facility (Airtanker website 2005).

Characteristics of the A330 include: a large fuel capacity, an advanced digital cockpit with fly-by-wire controls for excellent handling qualities and low crew workload, a fuselage cross-section maximized for both passenger and cargo payloads, and under-floor holds that accommodate NATO pallets.

1. Globalization Trends

There is a trend toward globalization in commercial aircraft production. In the 1960's U.S. commercial aircraft manufactures had a virtual monopoly on the world market. The landscape has changed significantly. Based on the contraction in the U.S. aerospace industry, fierce foreign competition, and the strategy of "industrial offset[8]"; the manufacturing capability is much more diffuse today. There are many innovative cross-border agreements, as well teaming and joint ventures. Furthermore, U.S. industry collaboration with one country's firm increasingly means collaboration with many other foreign firms.

[8] Industrial offset refers to a strategy of production sharing agreements with the importing country.

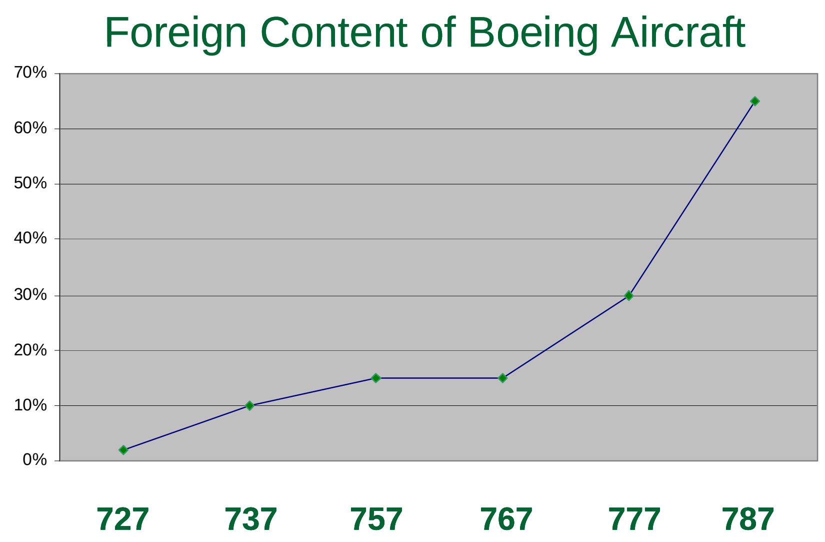

Figure 6. Foreign Content of Boeing Aircraft

Additionally, as figure 6 shows, although Boeing is a U.S. firm, foreign content of their commercial aircraft has risen from 2 percent for the B-727 in 1963, to 65 percent for the B-787 in 2004. This trend is not just from vendor and suppliers, but has extended to major airframe components (see Figure 7). These parts include wings, nose, keel beam, aft fuselage, front fuselage, center fuselage, center wing box, rudder, stabilizer, dorsal fin, vertical fin, and elevators (MacPherson 2002).

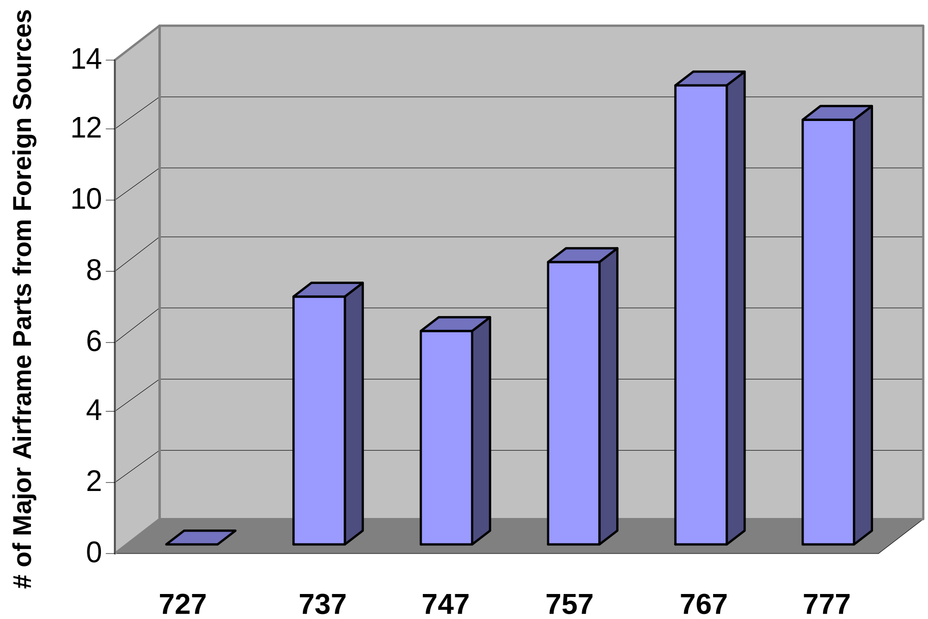

Figure 7. Number of Airframe Parts from Foreign Sources

On the other hand, many European systems have significant U.S. content. Specifically, in the tanker case, although the KC-30 aircraft is based on an Airbus airframe, Northrop Grumman claims that close to 60 percent of the aircraft content during Limited Rate Initial Production (LRIP) will be from the U.S. (these calculations are based on planned procurement costs, that include both cost of components and cost of labor) (MacPherson 2004) (Greider 1997) (National Research Council 1994) (Fingleton 2005) (Lawrence 2005).

2. Production Efficiency

Another major factor that significantly impacts the cost of an aircraft is the production rate. Aircraft manufactures strive to operate at an economical production rate: i.e. one which makes efficient and effective use of the existing manufacturing plant and facilities. Generally speaking, the higher the rate, the lower unit production cost, in that higher rates enable producers to spread fixed costs over a larger number of units and use more efficient production techniques and processes that are economically viable only at higher production rates.

As depicted in Figure 8, Point 1 is the maximum economical rate, and it occurs just before the planned plant capacity is reached. Point 2, illustrates the minimum economical rate, which occurs at the knee of the curve. This rate is the minimum production quantity that still permits the effective utilization of existing manufacturing facilities. Then, finally, Point 3 is the minimum sustaining production rate, which allows keeping production lines open, as well as maintaining a responsive vendor/supplier base.

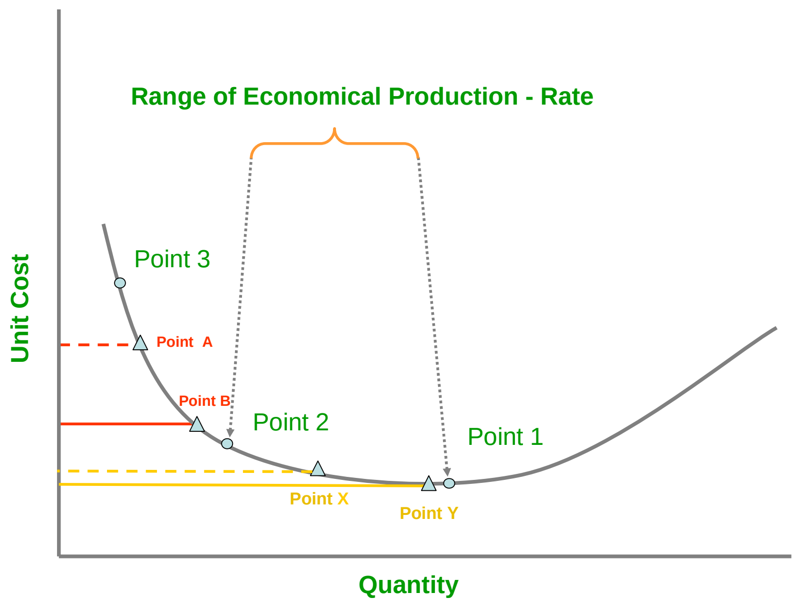

Figure 8. Production Efficiency (Worthington 1985; Worthington 1985)

Taking advantage of dual-use products can be especially valuable when pulling deliveries off an existing commercial production line. The DoD can leverage economies of scale, make guaranteed buys smaller, and minimize non-recurring costs. When commercial production is large, small variations in defense buys will have only a modest impact on unit cost (between Point Y and Point X in Figure 8). When the commercial production is small, however, small variations in defense buys can have a significant impact on unit cost (between Point B and Point A in Figure 8). Currently both prospective refueling tanker producers have commercial backorders through 2008.

D. Cost-Benefit Considerations

When developing an acquisition dual-source strategy for a complex, high technology weapon system such as the tanker replacement, the government should strive to get more than just the cheapest system. In fact, competition often provides other benefits such as higher quality, greater reliability, improved innovation, and an enhanced industrial base. However, competition can introduce costs as well as benefits (see table 9). In this section, we compare the qualitative benefits of a dual-source strategy, and address the issues most often brought up as the costs of dual-sourcing.

Costs
• Qualification of second source—minimal in the case of medium size tankers
• Non-recurring costs—low in the case of medium size tankers
• Perceived to require extra government management effort—may in fact be lower
• Logistics Considerations
Benefits
• Top People applied in a competitive environment
• Improved Innovation
• Industrial base considerations
• Better value (higher performance, higher reliability, at lower costs)

Table 9. Cost-Benefit Considerations of Competitive Dual-Sourcing

1. Costs of Dual-Sourcing

In our effort to understand the costs that accrue due to competition, in the case of the tanker replacement, we look at the requirement to qualify a second source, the additional non-recurring costs, the extra management effort required to manage a second contractor, and finally, the logistics considerations. Since, in many cases, the initial investment may be higher, coupled with the perceived higher risk, DoD has often been reluctant to use dual-sourcing. In the case of the tanker replacement, however, since both aircraft are commercially available, the required initial investment should not be a significant factor.

Non-Recurring Costs

In most defense acquisitions, qualifying a second source can be a major effort. First, if they are going to be building the same product, it can be difficult and expensive to create a good technical data package for the second contractor to use to begin production. This task is complicated by the fact that frequently government personnel are not experienced enough to judge the adequacy of the technical data. It can also be difficult to pass along manufacturing experience from the first contractor in an attempt to bootstrap the second source. As a result, it may take significant government effort to help get the second source into production. In this case, these issues are not a factor – the two proposed tankers are based on commercial platforms already in production. Therefore, requalification of the airframe should be minimal since the same airframe design and materials will be used for both the commercial and military versions.

Second, developing a second production source normally requires start-up costs for a second facility, capital equipment, training, etc. In this case, the Boeing KC-767 will be produced using the existing commercial production line. The Northrop Grumman-led team has plans to open a new KC-30 production facility adjacent to the EADS North America facility proposed for the Mobile's Brookley Downtown Airport. The cost of this investment, however, will be reflected in the proposed cost of the KC-30.

Perceived to Require Extra Management Effort

One of the major objections to developing and maintaining competition through production is the apparent extra management effort required on the part of the program office personnel and the DoD as a whole. Effective periodic dual-source competitions will require additional planning and effort to conduct the source selections. During the period of performance, the program office will have to administer two contracts, dealing with two quality control systems, two cost systems, and two configuration management systems. Additionally, these competitions introduce the possibility of disputes and lawsuits, with their accompanying program delays (Birkler 2001).

There are two mitigating arguments. While it may be inherently more expensive to develop, monitor, and coordinate with two contractors, the ever present competitive pressure is a most effective performance inducement. Therefore, with competitive dual-sourcing, we can expect the level of monitoring and coordination on the part of the government to be lower, and the contractor performance higher(Richardson 1995)—as was seen in the Great Engine War and the Tomahawk cases above. Additionally, when viewed within the scope of the potential savings on a large acquisition program, such as this tanker acquisition, if there are extra management costs they are generally greatly eclipsed by the magnitude of the savings.

Logistics Considerations

Producing and supporting two different aircraft, that would be used to fly the same missions, would normally have significant negative impact on the cost of logistics support. The "logistical dualities" could include additional maintenance personnel, spare parts, and training requirements to support the two different types of aircraft. However, in the case of the tanker, since these aircraft are based on widely-used commercial variants, the impact can be significantly reduced by leveraging the extant support infrastructure, with the contractor provided logistics support. This could take the form of a performance-based logistics contract which has been very successful in improving performance and reducing costs in other programs, and is currently emphasized by DoD policy.

Additionally, since air refueling tanker aircraft are a critical component of DoD's current and foreseeable strategy, having two different aircraft would provide a measure of resilience in the refueling fleet. If one or the other aircraft was grounded[9], the Air Force would still have the residual capability of the other aircraft.

2. Benefits of Dual-Sourcing

There is a great deal of uncertainty in the development of a major weapon system. The program's projections of schedule, cost, and performance are often the result of optimistic planning, and are frequently subject to significant errors. Identifying the best solution, with any degree of certainty is difficult, if not impossible. Developing and maintaining a second source for that system allows the government to hedge against that uncertainty and provides what Scherer identified as a statistical benefit of competition; it would be realized even if the competitors were unaware of each other. However, when the firms are also aware of the competition, their behavior changes to adapt to the competitive pressure. These are called "behavioral effects," and are generally beneficial to the buyer (Scherer 1964).

Therefore, the competition that results from a dual-source strategy is not an end in itself, but a means to several related benefits that constrain prices and prevent monopolistic pricing, including the continued support from the contractor's top people, improved innovation, better value, and increased industrial base.

Top People

Program performance in general, is directly dependant on people – the participating scientists, engineers, project managers, and all the others required to develop a successful program. But how does allocation of this highly skilled and critical input happen? Competitive pressure ensures firms put their best people on the job – obviously assuming that the firm is intent on winning the competition. If the pressure is removed, such as with a single-source award, the top people will be moved to the next big competitive effort. Competitive dual-sourcing will maintain that competitive pressure and incentivize the firms to keep their top people on these programs.

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[9] In the 1999, a KC-135E crashed in Germany. The problem was identified later as having been caused by a horizontal stabilizer trim actuator. Immediately after, flight restrictions were imposed on the aircrafts and the entire fleet was inspected, resulting in a sharp decline in KC-135 availability (32 percent of the fleet was in depot at the same time).

Improved Innovation

> "*Competition clearly influences costs. But it is also the driving force behind innovation. If we do not have a competitive defense industry, we lose out on both of our major weapon system objectives – affordability and high performance. This incidentally is why we believe that strongly regulated monopolies are the wrong direction for the defense industry*" (Gansler 2000).

Competition produces the critical pressure needed to stimulate and maintain innovation in the defense industry. Maintaining competition during the development phase spurs firms to devise ingenious approaches in fulfilling DoD's mission requirements. Preserving rival design centers counteracts technological lethargy or error, and hence enables DoD to exploit superior defense technology.

The real threat of competition during dual-source production drives increased efficiency. It incentivizes the two firms to continue to innovate, improve quality, and cut costs, in an effort to win a greater share of the planned production. Firms use techniques such as investing in value engineering, conducting cost reduction studies, improving production techniques, and identifying higher performance suppliers. These competition-driven innovations are key to the maintaining and accelerating of learning. Additionally, Anton and Yao found that when innovation is a key competitive dimension of dual-sourcing, the uncertainty introduced by the innovation process makes coordination between the competing firms more difficult. This increases the benefit of this strategy to the buyer (Anton 1992).

Sole-source procurements, on the other hand, allow firms to behave like monopolies. As well as being undesirable from a price standpoint, this also allows firms to restrict innovations from inside (or even from outside) the defense sector.

Industrial Base

The aerospace industry has unarguable played a pivotal role in establishing America's role as a global leader. It has provided products that assure the country's national security and economic prosperity (it is the single largest U.S. export action). Yet the

U.S.'s role in aerospace leadership is not assured. Therefore, when developing acquisition strategies for major systems, which can significantly alter the development of a nation's industrial base, it is best to identify the acquisition option which yields the greatest achievable benefits.

The U.S. aerospace industrial base is comprised primarily of privately owned entities. These private entities extend from the three remaining prime contractors, to their subcontractors, down to the suppliers and vendors of parts. There has been a significant consolidation since the end of World War II, when there were over 50 major aerospace industry producers. The two main reasons for a consolidation are the increasing level of technology and complexity associated with development of new aircraft, coupled with the corresponding decrease in total number of aircraft purchased—with added encouragement by Wall Street financial markets, and the perceived industrial benefits of reduced competition.

The question then is what impact competitive dual-sourcing has on the industrial base? Clearly, with competitive dual-sourcing for the same or a similar product; the industrial capacity to produce that type product is expanded. Additionally, since the aerospace sector is becoming increasingly globalized, initiatives that strengthen stable transnational partnerships will enhance national security. With a winner-take-all competition, the capacity to produce the product would actually decline.

Better Value

Employing a dual-sourcing strategy has consistently demonstrated that it can reduce prices. However, even more important than these reductions, there are other benefits that accrue from competition, which include higher quality and reliability, and improved contractor responsiveness. In the case of the tanker replacement, we anticipate that competitive dual-sourcing will result in all these benefits—and, therefore, a better value for the DoD and the U.S. taxpayers (see Figure 9).

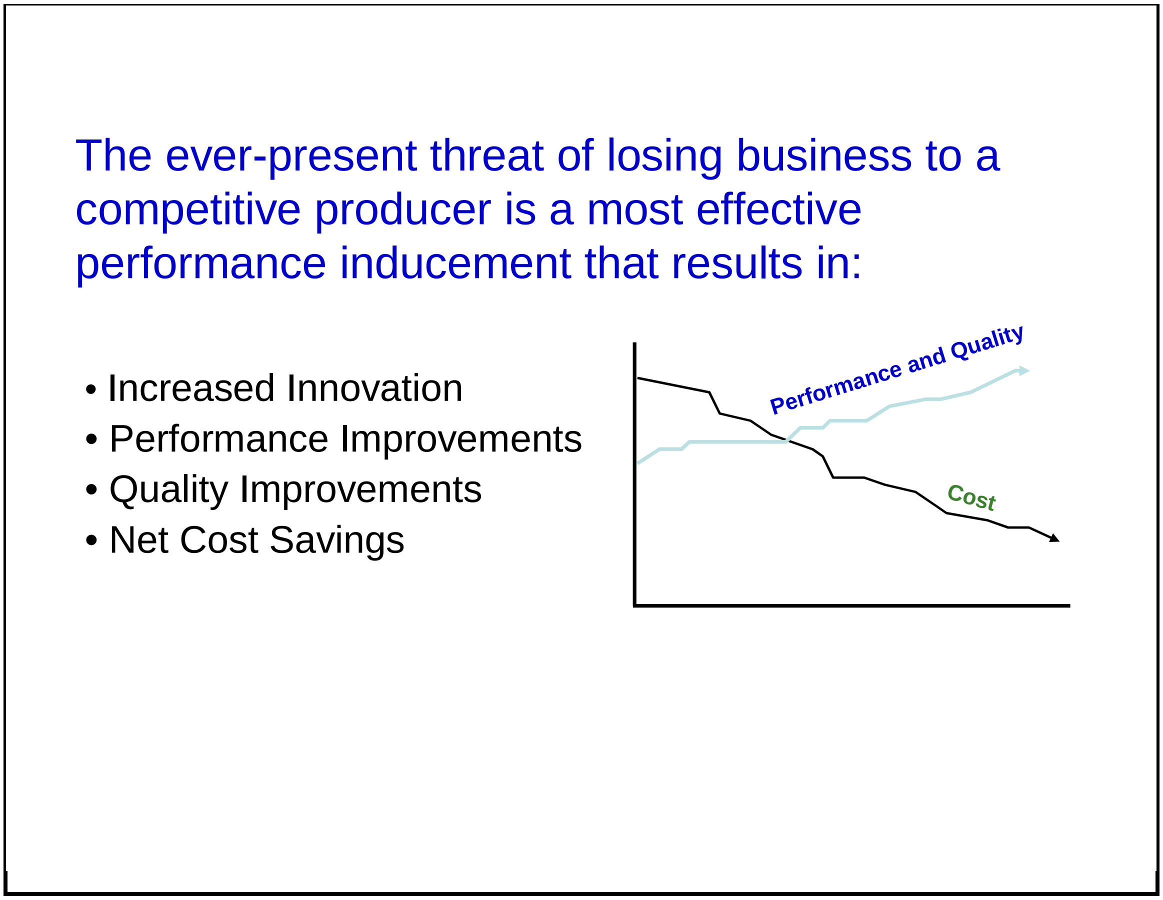

Figure 9. Better Value

V. Analysis of Tanker Strategy

We conclude our study with an examination of several acquisition strategies for the Air Force tanker replacement, with a focus on maintaining competition throughout production. The first step was to identify the three most likely tanker replacement acquisition strategies: winner-take-all, directed split-buy, and competitive dual sourcing (with similar bids or with significantly different bids).

In the winner-take-all strategy, the competition for production is held between multiple qualified contractors. Once the source is selected, that source would produce all of the tankers; as a result there are no more competitive pressures throughout the production cycle, with the elimination of the other production sources. With the directed split buy option, production is split between the two firms, but the split is pre-determined and directed by the DoD. Consequently, there is no head-to-head competition, and the government is effectively dealing with two, extended sole-source contractors, throughout the life of the program. Finally, with competitive dual-sourcing there is continuous competition throughout production. As a result, this strategy accrues all the cost, performance, innovation, and quality benefits of competition.

As discussed earlier, dual-sourcing works best for systems which need minimum development, or are already produced for the commercial market place. The tanker acquisition is exactly that – a developed system that is commercially available. This is very different from the case of the Joint Strike Fighter, a new high-tech system, where the RAND analysis concluded that competition during production (on the airframe alone) would increase the overall program costs (since it was a new item and only a small share of the overall recurring costs—vs. the engine and avionics)).

A. Analysis Assumptions

1) We assume that support warranties under both single and dual-sourcing are the same. Though the costs of warranties are likely to be significantly lower under dual-sourcing (based on the theory of monopoly pricing and as demonstrated

during the Great Engine War). However, to simplify our analysis, we do not include these differences.

2) We assume that aircraft performance and reliability for each bidder are similar. If the performance and/or reliability are significantly different, then cost adjustment must be made to ensure comparable value between the two proposed tankers. Increased performance and/or reliability could also be used to reduce the total aircraft requirement, or provide greater operational capability. Increased reliability (of one over the other) would also reduce life cycle cost.

3) We assume that with dual-sourcing, contractors compete in biennial competitions. However, we have conservatively assumed that the same contractor wins the same percentage of the bid for each contract period.

Note: If the preceding three factors were to be included in the analysis, they would clearly enhance the benefits of dual-sourcing.

4) We assume that an adjusted cost difference of less than $5 million per plane (4 percent difference) is not significant enough to shift the award from 50:50, which is the split that gives neither competitor an advantage for subsequent bids.

5) We assume a split ratio of 75:25 in favor of the lower bidder when there is a significant difference in adjusted cost (greater than 4 percent). The 75:25 ratio was selected to both get the best value, while maintaining the competitive pressure of a viable second source. Other ratios, such as 60:40, (which would be more effective in maintaining the competitiveness of the second source) would not significantly affect the conclusions of our analysis.

6) We assume that the commercial production lines remain open for the foreseeable future.

7) We assume that the government's personnel cost of competing will be greater, but not significantly relative to the other costs being considered.

8) We assume that qualification costs will be minimal, since both models are based on commercial airframes, and both have been modified and utilized as tankers. We also assume that non-recurring tooling and engineering will be minimal for the same reasons.

9) We assume that spare parts and contractor-provided logistic support will cost less under dual-sourcing (RAND used an estimate of 5 percent O&S savings in their analysis of potential competition on the JSF program) but we did not penalize the sole-source producer.

10) We assume that if a mix of large and medium aircraft is decided upon, as long as the suppliers are competitively selected (vs. a directed split), and the quantities of each are selected from existing commercial lines, the basic analysis still holds.

B. Competitive Scenarios

Based on the above assumptions, we examined four competitive scenarios:

(1) Winner-take- all

(2) Directed split-buy

(3) Similar bids (4 percent or less difference in bids)

(4) Significantly different bids (more than 4 percent difference in bids)

Since the specific costs and learning curve data are proprietary and were not available, we chose to estimate program cost growth using cost growth factors as discussed in section II. We then compared each scenario using optimistic, average, and worst cases Cost-Growth Factors. For DoD aircraft programs with no production competition, the Cost-Growth Factor, as discussed in Section II, ranges from 0.96 to 2.04 with an average of 1.46 (see table 4). For commercial aircraft produced in a competitive environment, the Cost-Growth Factor ranges from 0.73 to 0.98 with an average of 0.84 (see tables 5). The program baseline cost, total aircraft procurement cost, and potential cost increase/decrease are calculated as follows:

Program baseline cost = (Unit cost of aircraft at the beginning of the program) * (Number of aircraft)

Project program cost = (Program baseline cost) * (Cost-Growth Factor)

Potential cost increase/decrease = (Total aircraft procurement cost) – (Program baseline cost)

1. Scenario I – Winner-Take-All

In the first scenario, the winning bidder is awarded a contract to produce all 100 aircraft. We assume an initial winning bid of $125 million per aircraft, so that the program baseline cost amounts to $12.5 billion. In the optimistic case, we use a Cost-Growth Factor of 0.96, and the total aircraft procurement is then $12.0 billion. Thus, the potential cost decreases by $0.5 billion—the difference between the total aircraft procurement cost and the program baseline cost. By contrast, in the worst case where Cost-Growth Factor is as high as 2.04, the total aircraft procurement cost is $25.5 billion and the potential cost increases by $13.0 billion. Using the average Cost-Growth Factor of 1.46, the winner-take-all approach would cost a total of $18.25 billion for the aircraft procurement and increases the potential cost by $5.75 billion.

	Optimistic	**Average**	**Worst Case**
Unit Cost	$125M	$125M	$125M
Cost Growth Factor	0.96	1.46	2.04
Potential Program Cost Increase	($0.5B)	$5.75B	$13B
Total A/C procurement	$12B	$18.25B	$25.5B

Table 10. Potential Program Cost Winner-Take-All

2. Scenario II – Directed Split-buy

In the second scenario, DoD directs a split-buy and both contractors are selected to produce a fixed percentage of the required aircraft. We conservatively assume the winning initial bid is $125 million per aircraft from each contractor (more likely one would be higher); and subsequent buys are awarded non-competitively. However, without competitive pressure, both suppliers would be operating with sole-source learning, and each contractor would be producing fewer aircraft. As a result, each contractor would move along their sole-source learning curve less (we did not have the detail data to quantify), and the program costs would actually exceed those of the single, sole-source program (due to the higher non-recurring costs and smaller buys from each, with none of the competitive benefits). We anticipate that the best possible result from a directed split-buy would be a total program cost approximately the same as the first scenario.

3. Scenario III – Competitive Dual-Sourcing with Similar Bids

In the third scenario, since there is not a significant difference in the bids (or "adjusted bids" if the performance or reliability are different) the production is split 50:50 between the two contractors. We assume that the initial bids are $125 million per aircraft and in each subsequent year, the bids or "adjusted bids" are not significantly different from each other. Using the lowest Cost-Growth Factor with competition of 0.73, the optimistic case leads to a total of $9.13 billion in total program procurement cost. Thus, the competitive dual-sourcing with similar bids generates $3.38 billion in cost savings. Using the worst case Cost-Growth Factor with competition, 0.98, the program procurement cost is projected at $12.25 billion for 100 aircraft; a saving of $0.25 billion. With the average Cost-Growth Factor of 0.84, the third scenario projects the program cost to be $10.5 billion for 100 aircraft, which saves $2.0 billion when compared with the program baseline cost.

	Optimistic	Average	Worst Case
Unit Cost	$125M	$125M	$125M
Cost Growth Factor	0.73	0.84	0.98
Potential Program Cost Increase	($3.375B)	($2.0B)	($0.25B)
Total A/C procurement	$9.13B	$10.5B	$12.25B

Table 11. Potential Program Cost—Competitive Dual-Sourcing with Similar Bids

4. Scenario IV – Competitive Dual-Sourcing with Significantly Different Bids

In the last scenario, with significantly different bids (actual or "adjusted"), the lower bidder would produce 75 percent of aircraft, while the higher cost bidder would produce the remaining 25 percent. We assume initial adjusted-best-value lower bid is $125 million per aircraft, while the higher bid is 10 percent higher, or $137.5 million. Using the most optimistic Cost-Growth Factor of 0.73, the total program costs would be $9.35 billion, a potential cost decreases of $3.46 billion. With the worse case Cost-Growth Factor of 0.98, the total program would cost $12.56 billion, a potential cost decreases of $0.26 billion. Finally, if we assume the average cost growth factor of 0.84, the competitive dual-sourcing with significantly different bids scenario would cost the DoD $10.76 billion.

	Optimistic	Average	Worst Case
Unit Cost	$125M	$125M	$125M
Cost Growth Factor	0.73	0.84	0.98
Potential Program Cost Increase	($3.459B)	($2.05B)	($0.26B)
Total A/C procurement	$9.35B	$10.76B	$12.56B

Table 12. Potential Program Cost—Competitive Dual-Sourcing with Significantly Different Bids

5. Summary

In summary, in both the non-competitive production scenarios (winner-take-all and directed split-buy) the total aircraft procurement is projected to be $18.25 billion. With the competitive dual-source scenarios, significant program savings are projected, even if there are significant differences in the bids. If we assume average cost growth factors for both the non-competitive and competitive scenarios, **the competitive scenarios project more than $7 billion in program savings**.

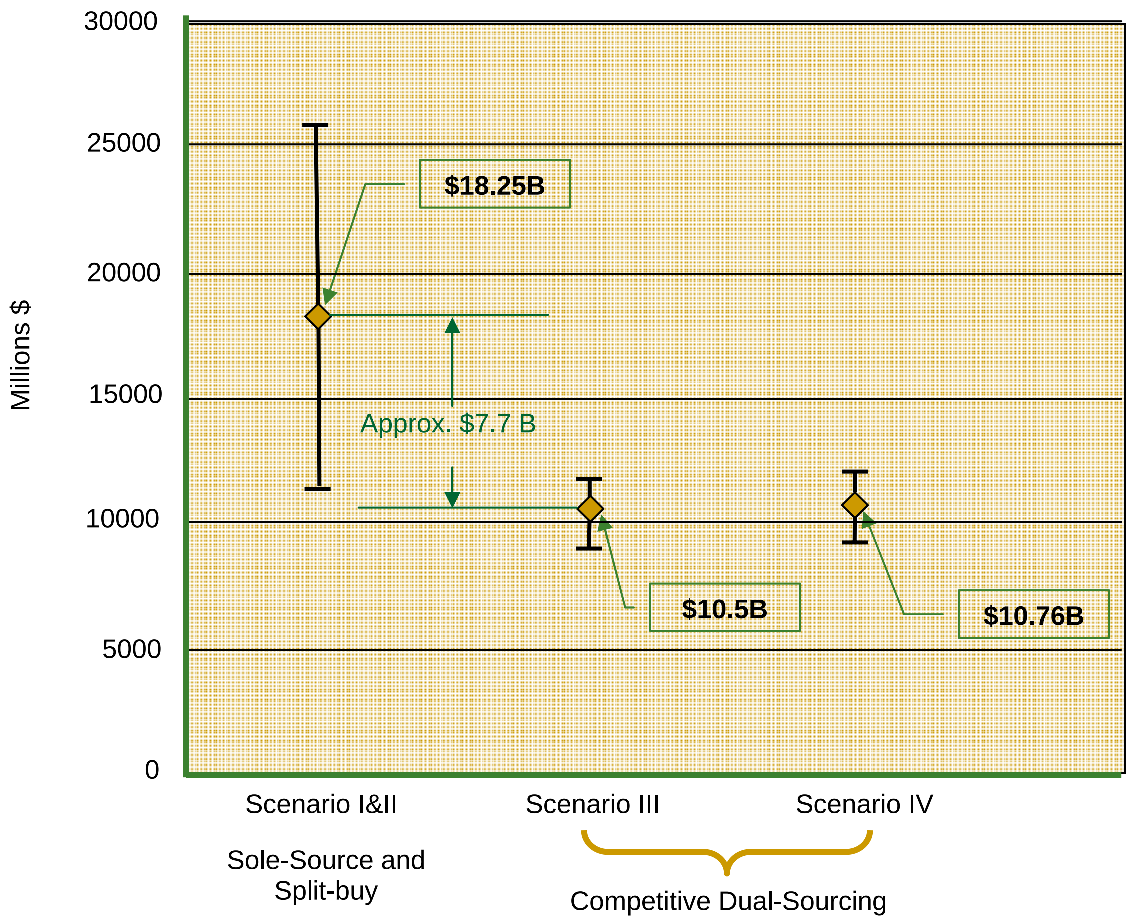

Figure 10. Summary Results of Four Scenarios

VI. Findings and Conclusions

We have examined the historic benefits of maintaining competition during production in general; and within the limitations of the data available to us, have projected the impact of maintaining a competitive environment during the production of the Air Force's tanker replacement aircraft. The principal findings of this report are:

1. Maintaining competition throughout a weapon system's procurement process, to include production, has many benefits. During production, competition increases learning for both the original and second producers.

2. The defense market is generally very different from the commercial market. And, based on consolidations in the defense industry, there are only a handful of contractors capable of developing and producing aircraft for the U.S. military. Consequently, even though the DoD is a monopsony buyer, competition is necessary to balance the power of the oligopoly suppliers.

3. The aircraft industry is becoming increasingly globalized. With the consolidation of the defense industry, multinational partners may be necessary to maintain both competitive pressure and the industrial base.

4. Dual Sourcing the replacement tanker acquisition has numerous advantages, as long as the commercial production is in place. First, the creation and maintenance of a competitive market that will reduce the overall program cost. Second, it incentivizes innovation, encourages product quality, improves the industrial base, and helps to provide a better overall value from the procurement. Finally, in the tanker case, dual-sourcing can also reduces operational risk by introducing a degree of resilience in the production and operation of the air refueling fleet.

5. The directed split-buy bears all of the costs of dual sourcing, due to the higher non-recurring costs of two contractors and the smaller lot sizes, but virtually none of the competitive benefits. As a result, the program costs could actually exceed those of the single, sole-source program.

6. There are several negative costs, but they are generally mitigated by the fact the replacement tanker is a modification of a commercial aircraft. This effectively means that the tanker is not a new development with a long design phase. It also means that the government can leverage the extant production sources, eliminating the cost of qualifying a second source, and, also, minimizing a significant share of the non-recurring cost of developing and maintaining two production facilities. Finally, since both aircraft are already in worldwide service, the logistics impact of maintaining two different aircraft should be minimal, if the DoD preferred, performance-based-logistics solutions are used.

On the basis of these findings we believe that maintaining two production sources for the replacement tanker is not only feasible, but, in fact, very desirable—saving over $7 billion; with improved performance. Additional study, however, is desirable to determine the optimal frequency for the production competitions and the lot sizes.

Mandatory competitive dual-sourcing, solely for the sake of competition, does not make sense. However, in many cases, it has significant benefits; and this tanker procurement presents the DoD with an exceptional opportunity. We believe that it would be a great benefit to the DoD, and to the U.S. taxpayers, to take advantage of it.

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