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COMPETITION IN WEAPON SYSTEMS ACQUISITION: COST ANALYSES OF SOME ISSUES

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and
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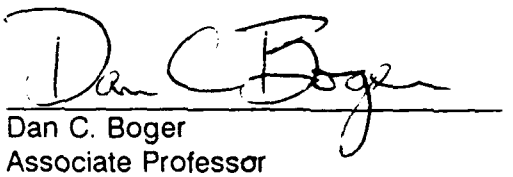

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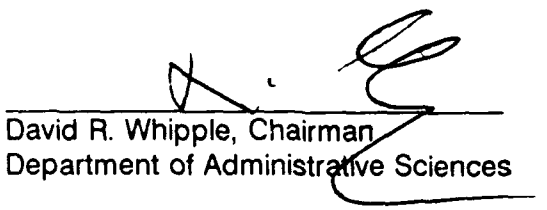

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COMPETITION IN WEAPON SYSTEMS ACQUISITION:

COST ANALYSES OF SOME ISSUES

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ABSTRACT

The Twenty-Third Annual Department of Defense Cost Analysis Symposium was held in Leesburg, Virginia, on 6-8 September 1989. A number of the papers presented at that symposium, as well as a roundtable discussion held at the symposium, were analyses of the costs associated with alternative competition strategies in weapon system acquisition. The papers and the transcript of the roundtable discussion included in this compendium were selected from those presented at the symposium which addressed the general area of weapon system competition. The papers and discussion fall into three broad areas addressing the costs and benefits of competition: methodological analyses, empirical analyses, and analyses of policy and implementation. They represent those efforts which best reflect state-of-the-art research into the issues surrounding the costs associated with alternative strategies for weapon system competition.

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INTRODUCTION AND SYNOPSES

1. INTRODUCTION

The Twenty-Third Annual Department of Defense Cost Analysis Symposium was held in Leesburg, Virginia, on 6-8 September 1989. A number of the papers presented at that symposium, as well as a roundtable discussion held at the symposium, were analyses of the costs associated with alternative competition strategies in weapon system acquisition. Competition, as the term is used in the field of weapon system acquisition, refers to the presence of more than one, but usually only two, contractors, or sources, for the development or production of a weapon system. The introduction of a second source for development or production is referred to as dual sourcing.

The issue of whether to compete, or more specifically, to dual source particular weapon systems at specific stages in their acquisition lifetimes is an important one. There are advantages and disadvantages associated with competing the various acquisition stages of a weapon system when compared with having only a single contracting source provide all stages of acquisition. If the acquisition is competed, advantages which may be realized are lower life cycle (or at least acquisition) cost, better performance, and an accelerated production schedule for the weapon system. On the other hand, there are disadvantages, usually realized as costs that may be substantial, associated with setting up the second source. These ramifications are discussed in detail by the papers in this volume.

The papers and the transcript of the roundtable discussion included in this compendium were selected from those presented at the symposium which addressed the general area of weapon system competition. They represent those efforts which best reflect state-of-the-art research into the issues surrounding the costs associated with alternative strategies for weapon system competition. Synopses of the papers and the discussion are in the following section of this chapter. The papers and transcript of the discussion appear in succeeding chapters.

The papers and discussion fall into three broad areas addressing the costs and benefits of competition: methodological analyses, empirical analyses, and analyses of policy and implementation. At the methodological level, the paper by Boger, Greer, and Liao and the paper by Beltramo address issues which lie at the root of all analyses of competition in weapon system acquisition. In the second area, empirical analyses of the effects of competition in production are provided by Tyson and by Flynn and Herrin. An empirical analysis of the effects of competition during the development stage is presented by Dembroski and Bohn. The third area, competition policy and implementation in defense acquisition, is addressed by the roundtable discussion of Carlson, Hamre, and McNicol which was moderated by Nussbaum.

2. SYNOPSES

Boger, Greer and Liao

Following a great deal of publicity concerning defense procurement scandals in the early 1980's, Congress enacted the Competition In Contracting Act of 1984 in an attempt to open defense acquisition to more competition. This paper attempts to separate the myths from the facts of weapon system competition. It is unfortunate that many policy analyses, as well as many major acquisition decisions, have been based on the myth that competing weapon systems will always produce significant savings to the government. The fact is that dual source competition

in major systems introduced prior to the mid-1980's has resulted in additional costs to the government almost as often as it has produced savings. The paper provides a discussion of contractor forward-pricing strategies, in general, as well as a detailed examination of several of the deficiencies associated with dual sourcing when used as an approximation to competition.

Beltramo

This paper identifies and discusses data and analytical methods used to evaluate the economic effects of production competition. It shows that there exist significant problems concerning the current state of data used to assess the efficacy of dual sourcing. The paper discusses the usual, baseline technique of measuring the effects of competition as well as alternative techniques, and it points out that all methodologies have deficiencies. A problem common to all approaches is that they focus on individual programs instead of the overall profitability and sustainability of the entire firm. Given the current policy thrust toward joint-ventured or teamed development programs, conclusions about the economic effects of competition using any of the discussed assessment technique must be carefully drawn, and those conclusions remain case-sensitive in nature.

Tyson

After reviewing the advantages and disadvantages of competition in weapon system acquisition, this paper presents a standard method for evaluating the impact of production competition on program costs. Typical applications are then discussed. The paper then presents the results of case studies of cost and schedule outcomes of 64 major programs of which 13 are competitive. In addition to the case studies, several other studies of dual-sourced programs are reviewed.

The principal results of the analyses are, first, that there is no statistically significant difference in cost growth between competitive and non-competitive acquisitions and, second, that cost growth under competition is actually higher than under sole source procurement. Additionally, the analyses show that production quantity growth is much higher and program stretchout is much lower under competition. This may indicate either that stable programs are chosen for competition or that the government keeps competitive programs more stable in an attempt to recoup its investment in the second source. Detailed findings and conclusions are also presented.

Flynn and Herrin

This paper presents the results of an analysis of the costs of dual sourcing twelve major Navy programs. After explaining the methods and assumptions made in the study, the authors present their results both in terms of estimated net savings due to dual sourcing and in terms of price changes of both the original and second sources observed over time. Using two scenarios which vary the times over which the government can recoup its investment in the second source, the authors find estimated net savings of 14% through fiscal year 1994 and estimated net savings of 12% through fiscal year 1989 totaled across the twelve programs. All twelve programs show net savings in the longer run scenario, while eight programs show net savings in the shorter scenario. The net savings are dollar weighted, so that larger dollar savings are more important in the final net savings figures.

In comparing the pricing behavior found in dual sourcing over time, the authors find that competition between the first and second sources appears to intensify over time. They also find that the application of downward rotations to learning curves due to the effects of competition may be inappropriate. They further find that the pricing behavior of the second source largely

determines the savings outcome of the competition; when the second source fails to beat the price of the first source, savings tend to be small, and conversely.

Dembroski and Bohn

This paper presents the initial results of a study to determine the effects of competition during the development stage of the acquisition of major weapon systems. Prototype competition, advanced development competition, and competitive fly-offs of alternative systems are examined. Although there is limited historical experience in the use of development competition in major weapon system acquisition, this study identifies evidence of a reduction in production unit cost growth and/or increases in quality, producibility, and contractor responsiveness for programs using development competition. The extent of these effects depends upon the selection criteria used during the contractor selection process. Thus, the use of competition during development is found to motivate the contractor to respond to the objectives that appear important to the government. This indicates that a successful development competition must begin with a clear indentification of the government's priorities.

Roundtable Discussion

In a wide-ranging discussion of competition policy and implementation in the Department of Defense, the roundtable begins with an assessment of the adequacy of both data and analysis for determining the effects of competition. The implications of this adequacy for various parties' overall assessments of the efficacy of competition are also pursued. The discussion then focuses on the determination of which particular weapon systems may be more attractive for dual sourcing. Switching to an assessment of alternative acquisition strategies encompassing dual sourcing, the discussants evaluate the strategy of having two contractors team during

development followed by their competing during prodution. The discussion then turns to the question of whether economic goals are the most important during dual sourcing. The roundtable ends by addressing the future of dual sourcing in the Department of Defense.

COMPETITIVE WEAPON SYSTEMS ACQUISITION:

MYTHS AND FACTS

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After publicity concerning $640 toilet covers, $436 hammers and other procurement problems, the Executive, the Congress, and the general public began pushing to open defense acquisition to more competition. As a result, Congress enacted the Competition in Contracting Act of 1984, Public Law 98-369. Due to this strong legislative and political pressure, "Think Competition" has become a slogan in defense acquisition circles, and dual source procurement has been suggested as one means of obtaining additional competition.

The purpose of this paper is to separate myths from facts in weapon system competition. It is unfortunate that many policy analyses, and many major acquisition decisions, were based on the myth that competing weapon systems would produce significant savings to the government.

The paper is organized as follows: Section 1 describes the pressure faced by the Department of Defense (DoD) to increase the use of competition in procurement. Section 2 discusses the unique DoD market environment, while Section 3 reviews prior studies which demonstrate the paradox that competition has resulted in added net costs to the government as

often as it has produced the desired net saving. Sections 4 and 5 present some theoretical and empirical data that explain the paradoxical findings. Section 6 summarizes myths and facts in weapon system competition and concludes with directions for future study for acquisition policy.

1. COMPETITION IN DEFENSE ACQUISITION

There is a deep-seated and historic belief that the best model for government procurement is solicitation of price offers from a maximum number of qualified sources. Indeed, there are many advantages to the government of competitive procurement if it is applied properly. Various imperatives for competition in defense procurement will be discussed in this section.

Since 1809, Federal statutes, regulations, and executive orders have consistently required that government procurement must, to the greatest possible extent, be made on a competitive basis. In 1965, then Secretary of Defense Robert S. McNamara indicated to the Joint Economic Committee (Hearings on the Economic Impact of Federal Procurement) that the General Accounting Office (GAO) had evidence of dollar savings on the order of 25 percent or more when competition was introduced for reprocurement of an item which had a sole-source procurement history [1]. Since then, this 25 percent savings figure has been quoted repeatedly by defense policy makers and observers. In 1969, the Subcommittee on Priorities and Economy in Government of the Joint Economic Committee called for vastly expanded use of competition for procuring all forms of Defense Department material [2].

This position has been reaffirmed both by the current Administration and by Congress. The most recent legislation is Public Law 98-369, which includes the Competition in Contracting Act of 1984. PL 98-369 stipulates the use of dual sourcing by DoD and civil agencies in procurement. The President's Blue Ribbon Commission on Defense Management (a.k.a., the Packard Commission) also strongly advocated the increased use of competition [3]. This drive

toward competitive procurement is reflected in various internal DoD initiatives and programs.

2. DEFENSE MARKETS

Defense markets run the gamut from totally free competition to a DoD-created market with one buyer and one or two suppliers; from markets which provide many choices of product and product attributes to one in which a product exists only because the DoD has paid the price to create it. While a great majority of the 13 million annual procurement actions are conducted in a purely competitive fashion, the majority of defense procurement dollars have been spent in a market where the government is the only buyer and the number of potential suppliers is small. In FY 1985, noncompetitive contracts awarded by DoD totaled $96 billion (underline in original) [4].

Competition in traditional markets arises when buyers and sellers are numerous and individually so unimportant in the market that their separate actions have no meaningful impact on market price. A great majority of DoD procurement actions are in such a market. However, the majority of procurement dollars are for major weapon systems which poses a unique problem.

For major systems, the government is the only buyer. It dictates the size of the market and the timing of demand. Additionally, these systems usually involve state-of-the-art technologies, and hence bear little relation to the infamous ubiquitous "widget" which is produced and sold in traditional competitive markets. Compounding these uncertainties to the supplier is the heavy investment needed to become a supplier. In this kind of environment, the availability of suppliers may be linked to the willingness of the government to absorb at least part of the risk, which could mean that the government must incur investment cost to develop a supplier in order to introduce a competitor. This is an element which is unique to the major defense systems market and is not well understood by those unfamiliar with the defense market. Lack of understanding of the

uniqueness of the defense market contributes to the illusion that competition in defense acquisition always produces lower prices to the government.

3. GAINS AND LOSSES FROM PRIOR DUAL SOURCE COMPETITION

Since McNamara's statement about the 25 percent savings from introducing a competitor, numerous studies have been conducted to examine the financial consequences of dual source competition. Earlier studies, with questionable methodologies, reported dramatic savings from introducing a competitor. These earlier studies are discussed elsewhere [6 through 9]. Despite their questionable methodologies, these studies were prominently cited as evidence of savings from introducing competition to weapon systems; Cohen [5] is an example. With the improvement in research methodologies, studies conducted in recent years revealed that competition has resulted in added net costs almost as often as it has produced the desired net savings. A comprehensive survey of prior studies can be found in the literature[6, 7, and 8] and, therefore, will not be repeated here. We will pursue the contradictory findings and provide additional insight concerning the inconsistencies.

Although many dual-sourced weapon systems programs have been studied, we will examine only those with verifiable data. Our interests are not on predicting the size of dollar savings but on pursuing the paradoxical finding that dual source competition has resulted in added costs as well as net savings. Hopefully, these efforts will provide some leads for the direction of future policy analysis.

Table 1 lists seven dual-sourced programs which have been examined closely in several studies [9 and 10]. The program savings (losses) data were taken from earlier studies, and the amount of savings (losses) was calculated by comparing actual prices paid by the government after the program was dual sourced to the amount that would have been paid had the

Table 1

Relationship Between Savings and Economic Environment

(1) Procurement Program	(2) Savings or (Loss) Due to Competition[a]	(3) Time Period in Dual Source Phase	(4) Average Capacity Utilization During Dual Source Phase
TOW Missile	26.0%	1971-75	63.5%
Rockeye Bomb	25.5	1972-73	70.9
Bullpup AGM-12B	18.7	1961-64	76.2
Shillelagh Missile	(4.7)	1968-69	87.0
Sparrow AIM-7F	(25.0)	1977-80	81.6
MK-46 Torpedo	(30.9)	1966-69	91.6
Sidewinder AIM-9D/G	(71.3)	1963-71	82.3

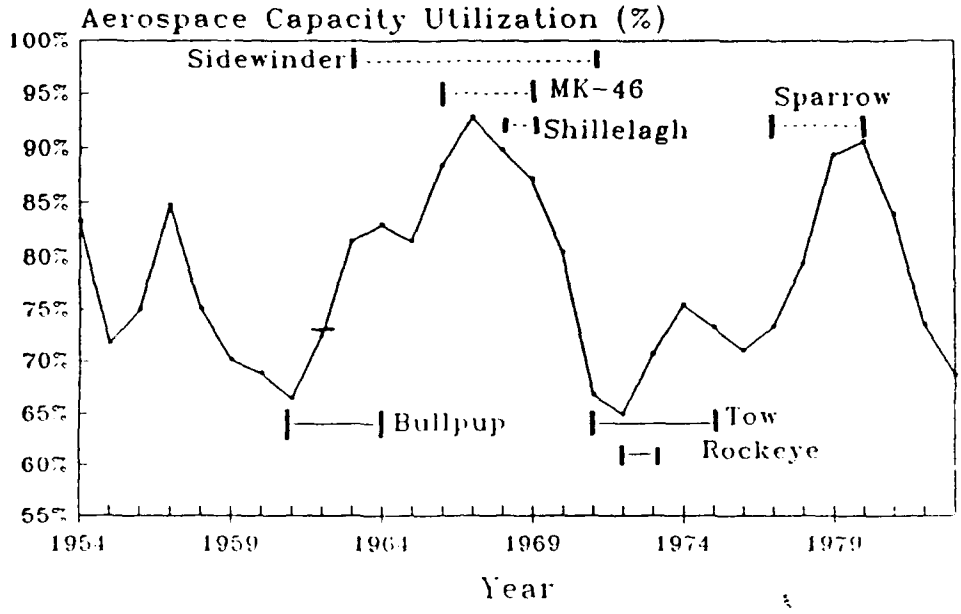
[a]From Beltramo and Jordan [9]

government continued sole source procurement.

We examined the time period during which each program was in the dual source competition mode, as shown in Column (3). The aerospace industry's capacity utilization rate during the dual source phase of each program is shown in Column (4). Note that the three programs realizing savings from dual sourcing were in the dual source procurement phase when the aerospace industry's capacity utilization rates were relatively low. On the other hand, the other four programs, which resulted in losses, were in the dual source procurement phase when the industry's capacity utilization rates were relatively high. It should be apparent to the reader that the likelihood of realizing savings or suffering losses from dual sourcing a major weapon system is related to the business environment of the industry.

Figure 1 shows the same data in chronological order. From a historical perspective, the three dual-sourced programs which resulted in saving to the government (Bullpup, TOW, Rockeye) coincided roughly with either the post-Korean-war era or the post-Vietnam-war era. On

Figure 1
Capacity Utilization & Dual Sourcing



the other hand, dual sourcing Sidewinder, MK-46, and Shillelagh resulted in additional cost to the government because they coincided with the height of the Vietnam war when the aerospace and the ordnance industries were at their busiest since WW II. It is clear that creating a second source as the "competitive" supplier does not always result in a competitive environment in an economic sense. Whether or not the government can realize the benefit of competition depends on the timing of dual sourcing. In the next two sections, we will provide additional insight to illuminate this point.

4. CONTRACTORS' FORWARD-PRICING STRATEGIES

The analysis in the preceding section suggests that contractors adjust their bid prices according to the business environment of their industry. Given the multitude of laws and regulations governing the government contractors' cost accounting and pricing, one might

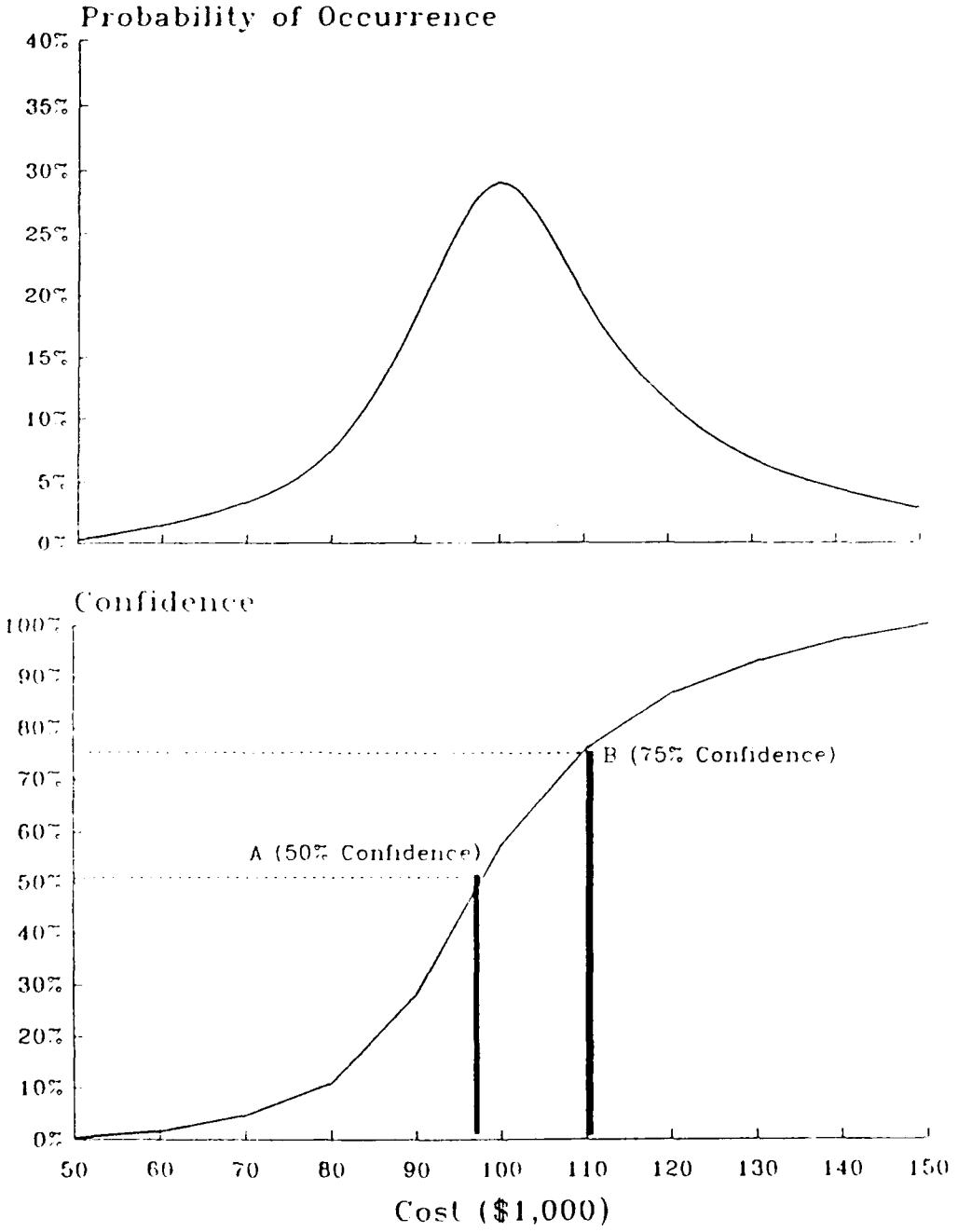
wonder how it is indeed possible to have varying levels of prices. To understand why this is possible, it is necessary to understand the forward-pricing system used in defense and other large civilian contracts.

Under the forward-pricing system, a bid price must be submitted well in advance on the often highly uncertain estimated cost to perform the contracted work. The uncertainty factor is particularly serious for defense contracts, since most involve state-of-the-art technologies. When the industry has ample idle capacity, such as in a post-war era, a firm may be so eager to compete for a contract that it will base its bid on an estimated cost figure which it may only have a small chance of achieving Figure 2 depicts this decision scenario. This hypothetical example assumes that the estimated cost to complete a contract ranges from the highly optimistic $50,000 (only 0.5% chance of achieving this cost figure) to the worst case scenario of $150,000. The top frame shows the estimated probability of occurrence of each cost figure. The bottom frame shows the cumulative probability of, or the chance to equal or better, a particular cost level.

Point **A** in the bottom frame of Figure 2 shows the estimated cost if the contractor is willing to accept a 50:50 chance. The corresponding cost estimate for the contract is approximately $98,000. The contractor may add another 10% as his profit target and submit a bid of $107,800 in the hope of winning the contract.

On the other hand, the contractors do not face any pressure to submit a competitive bids if business conditions in the industry improve and each firm has ample business opportunities. There are several reasons for this. For one, during an economic boom, a profit making firm is less likely to engage in price competition. This reduced willingness to compete in price would be further compounded if a contractor senses that other potential contractors also share this reduced willingness to compete. A booming economy also implies alternatives for the firm's production capacity. Sufficient profit opportunity must exist in order to justify capacity expansion,

Figure 2
Cost Uncertainty & Bid Prices



and, before the capacity can be expanded and made operational, existing projects must compete with each other for the limited capacity. Under all these circumstances, a contractor will not submit a bid unless he/she is highly confident that the estimated cost level can be equaled or bettered.

If the contractor desires a higher confidence level, say 75%, the estimated cost would be approximately $110,000, as shown in Point **B** in Figure 2. Adding a 10% profit target would bring the bid price to $121,000, a much higher bid compared to the $107,800 when the economy is not as good. Therefore, there is a close association between a contractor's bid price and the condition of the economy. This deduction is consistent with the empirical observation made in the preceding section that the potential for the government to realize the benefit of weapon system competition depends on the timing of dual sourcing.

5. STRUCTURAL DEFICIENCY OF DUAL SOURCE COMPETITION

Apart from the timing issue discussed above, there is a structural deficiency in the way a major weapon system can be procured competitively. Dual source competition allows the contractor and the government opportunities to exploit the market situation to the advantage of each party. The government's objective, as reflected in PL 98-369 and other policy directives cited earlier, is that competition will put competitive pressure on the supplier and result in a fair price to both parties. However, dual source competition also creates opportunities for the contractor to exploit. First, in return for the competitive market pressure with competitive bidding, the government gives up much of the regulatory authority it enjoys over verification of the contractor's cost and pricing data. Thus, it becomes easier for the contractor to obtain higher profits under a dual source competitive contract than under a sole source negotiated contract if the market environment allows it. Second, in order to maintain two sources of supply, it is

necessary for the government to award a minimum sustaining quantity to the higher-priced competitor. Both of these factors put the government in a disadvantaged position in dealing with the contractors. In this section, we will discuss various pricing strategies that can be used by the contractor to exploit the dual source competition situation. For a detailed discussion of these strategies, see Boger and Liao [11].

The Minimum Sustaining Rate

In a dual source competition environment, the lower-priced bidder is typically awarded the major portion of the annual quantity, but the higher bidder is also awarded a quantity that represents the minimum level of production the contractor requires to stay in production and remain viable. This guarantee, resulting from the government's desire to maintain two viable production sources, actually diminishes competitive pressures and puts the government in a disadvantaged position. Hence, there is no competitive incentive for the suppliers at the minimum sustaining quantity level, and the government can expect an inflated bid price from both of the suppliers at this level.

The Production Rate Effect

Due to the splitting of the production quantity between the two contractors, the government must forego some of the savings associated with cumulative production experience. The smaller production rate also means higher unit cost because neither contractor is able to fully realize the economies of scale in production. Therefore, the split award should result in higher production costs to either of the two contractors than if the entire year's production were awarded to the low bidder. The argument for using dual source competition, of course, rests on the assumption that the loss of economies of scale and cumulative production experience should be

more than offset by the smaller amount of profit the contractor would be forced to accept under competition. Therefore, it is usually suggested that the bid prices should be lower under a competitive environment, compared to a sole source acquisition, thus resulting in net savings to the government.

Unequal Competitive Position Between Contractors

If the second supplier is established after the first supplier has had some production experience with the weapon system in question, the competitive position of the two contractors most likely will be unequal. Under this circumstance, the anticipated competitive pressure from dual sourcing may diminish, or even evaporate completely.

First of all, being the developer of the system and having had some production experience, the first supplier often enjoys a cost advantage over the new supplier. Other things being equal, the more experienced producer will have a lower production cost and can underbid the new supplier. This problem is compounded if the first supplier continues to win the majority of annual quantities in a dual award environment.

Second, there is a dilemma facing the government in establishing the second supply source. Being the only buyer in the major weapon system market, the government often has to provide financial resources to induce other contractors to establish the production facility for a particular weapon system. Expanding the capacity beyond the level needed clearly is not economical. But the combined production capacity of the two firms may far exceed the actual requirements if the second source is established at the same production capacity level as the original source. On the other hand, if the second source's production capacity is established at a level lower than the total government requirement, the second source would not be in a position to bid at the higher percentages of the annual requirement, thus creating a virtual monopoly for

the original source at higher quantities.

Evidence of Contractor Price Gaming

The various scenarios discussed in this section reflect the structural deficiency of dual source competition, which presents many opportunities for contractors to submit inflated bid prices. This hypothesis is consistent with the forward-pricing strategy discussed earlier in providing the explanation for the paradoxical results of prior dual sourcing experience. To support our logical hypothesis, we will present an actual case which reflects the price gaming hypothesis discussed above.

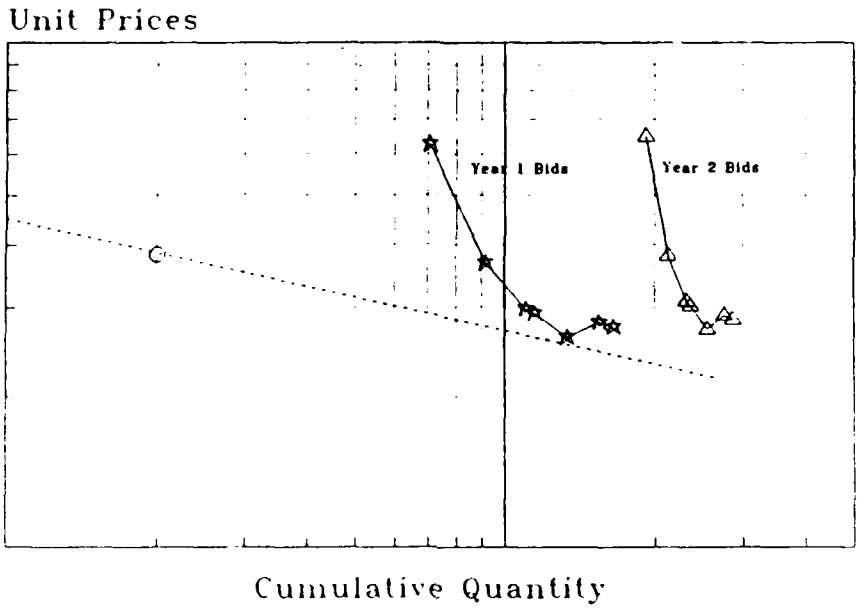
Figure 3 shows the bid prices submitted by a contractor of a major weapon systems under the dual source competition environment. We have masked the identity of the program and contractor and the numerical values of the data in order to protect the proprietary information, but the relative scale of all prices is accurate.

The circle on the left in Figure 3 is the actual unit price awarded when the contractor was the sole source supplier. The dashed line going through this circle and extending downward to the right is the projected sole source price using the contractor's historical price-reduction curve.

In dual source competition, the government annually solicits bids from both suppliers for various quantity levels. The lower price bidder is awarded the larger share of the government's annual quantity requirements while the higher price bidder gets the smaller share, usually the minimum sustaining rate to keep the loser's plant active. The stars on the solid line represent the bid prices for the respective quantity levels (from 20% to 80% of total annual quantity at 10% increments, also known as the step-ladder bids) submitted by the contractor in the first year of dual source procurement. The triangles represent the second year bids.

For comparison, the dotted lines beneath the bid price curves represent the reasonable

Figure 3
Price Gaming Under Dual Sourcing



step-ladder bids. On a log-log graph such as Figure 3, these bids should form a downward sloping straight line to reflect the production rate economies for larger quantities. The dotted line should also intercept the dashed long-term price reduction curve to reflect the effect of learning from cumulative production experience. Comparing the step-ladder bids to the respective reference line, one can observe several irregularities in those annual bids.

First, at the minimum sustaining rate (20%) level, the bids for both Year 1 and Year 2 are far above the reasonable bid line, indicating that the bid prices are too high at this quantity level. This reflects the point made earlier that, at the minimum sustaining rate level, there is no competitive pressure whatsoever and, no matter who wins the larger share, the other contractor will be a "happy loser."

Second, the bid prices went up for the 70% and 80% quantity levels. As the reasonable bid price curves show, the higher the quantity produced, the lower the unit price should be.

Increasing the bids at high quantity levels is not economically justifiable and reflects the point made earlier that, if one contractor senses no competitive pressure from the other side at that quantity level, it can and will take advantage of the situation.

Another irregularity is that Year 2 bid prices were higher than those in Year 1. Since the data have been adjusted for inflation, it is reasonable to expect decreasing prices for subsequent years because of the learning curve phenomenon typical in the aerospace industry. These increasing prices are another example of price gaming which is made possible under dual source "competition".

6. CONCLUDING REMARKS

Due to the unique market structure, procurement of major defense systems until recently was done primarily on a sole source basis. Current policy calls for expanded competition in procuring all forms of defense systems and material. Dual source competition has been suggested as one means of obtaining competition in the major system procurement. However, extensive study of prior dual source competition experiences indicates that the results from this form of competition have been mixed.

In this paper, we have provided some conceptual and empirical explanations for these paradoxical findings. Our attempt is to separate the myths from the facts of major weapon system competition:

Myth: Dual source procurement is a competitive procurement.

Fact: In economic theory, competition implies that there is a large number of suppliers and an individual supplier's action has no significant impact on the market. Dual source procurement is a classic case of duopoly which is, in fact, much closer to monopoly than to competition.

Myth: Dual source "competition" will force the suppliers to reduce their prices.

Fact: The primary condition under which the two suppliers in a defense industry duopoly would engage in price competition is when both are hungry for business, i.e., when the industry is in a slump. Even in this case, both suppliers can inflate the bid price at the minimum quantity without any penalty. Thus, at the minimum sustaining rate under the dual source procurement structure will always produce a "happy loser."

Myth: Dual sourcing a previously sole-sourced weapon system can produce savings on the order of 25% or more.

Fact: This myth was the direct result of McNamara's comment and has been quoted repeatedly by Washington decision makers in the past two decades. It is possible that this figure may be valid for a particular program, but there are many counter-examples. The size of savings and losses from dual sourcing varies. The fact is that the government must pay for introducing a second supply source in the form of initial investment, loss of economies of scale, and inflated prices for the minimum sustaining rate. Therefore, whether or not the government can realize savings from dual sourcing a major weapon system depends on the economic condition of the aerospace and ordnance industries. If the suppliers do engage in price competition, savings from the lower prices must be larger than the price the government paid for introducing the second source.

Understanding the myths and facts of major weapon system procurement is crucial in setting acquisition policies. Under a competitive bidding environment, as currently assumed by dual source procurement policy, the contractor can charge what the market will bear. On the other hand, under a monopoly environment, the contractor must substantiate all cost figures. Since dual source procurement is in reality closer to monopoly than to competition, regulations must be modified to eliminate those structural deficiencies of the current system.

In addition to separating myths from facts, our analyses of dual source competition policy also provide additional insights into contractors' pricing decision processes. We believe that these additional insights can shed some light on the direction of future policy studies. Clearly, the numerous attempts by the government to develop a method to quantify potential savings (as opposed to potential savings as well as losses) from dual source competition were misdirected. Our analysis shows that it is possible to determine the optimal timing to introduce a second source (or not to introduce it at all), but it would be futile to assume only savings result and then attempt to estimate the size of potential savings.

We believe that future policy research should focus on other viable alternatives to enhance competition at the major system level. These include major component breakout and multi-year contracting, among others.

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ESTIMATING THE ECONOMIC EFFECTS OF COMPETITION

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About three decades ago Secretary of Defense Robert McNamara endorsed the cost saving attributes of competition in defense procurement. He also set a standard of 25 percent for expected savings. A large body of research has since attempted to confirm or contradict his dictum. Many estimates of added costs or savings due to competition have resulted. Those estimates result from *a posteriori* assessments about what an item would have cost without competition.

This paper identifies and discusses analytical methods used to evaluate the economic effects of production competition. It does not promote one over another, rather it shows that all methodologies have serious deficiencies. Therefore, conclusions about the economic effects of competition must be carefully drawn and are case sensitive in nature.

1. WHAT ARE WE TRYING TO DO?

Most competitive programs have followed a period of sole source production. Many have been analyzed to determine the economic effects of competition. Several methodologies have been employed for this purpose but most follow similar steps. They are:

- Obtain historical cost data including
  - Nonrecurring costs to establish competition.
  - Initial (sole) source recurring production costs.

- Competitive production costs for both sources.

- Estimate the sole source cost for the competed quantity.

- Compare the actual competitive cost (including nonrecurring and marginal recurring costs) with the hypothetical sole source cost.

- Determine the effect of competition on procurement cost.

However, these methods differ regarding their estimates of the sole source cost and the explicit and implicit assumptions they incorporate. In addition, there are often discrepancies and uncertainties about the content and nature of the available data. Both of these issues are discussed below.

2. PROBLEMS WITH NONRECURRING COST DATA AND THEIR TREATMENT

Problems with available data cut across all analytical methodologies. Furthermore, they underscore differences between a competitive environment (including one where competition is threatened) and a sole source atmosphere.

Industry often allocates nonrecurring costs to establish a second source. These costs are expended for: technology transfer, additional tooling and test equipment required by the second source, and educational units produced to qualify the second source. In addition, the government generally needs additional staff to oversee the establishment of a second source.

The identification of all nonrecurring costs would seem to be a straightforward task. But that is not the case. Government does not record and track its costs related to selecting, qualifying, and managing a second source. Furthermore, the initial source often receives additional contract awards to assist with engineering problems experienced by the second source after competition has begun. Failure to identify these expenditures understates nonrecurring costs.

This raises the important issue of the difference in content between sole source and competitive production contracts. Sole source production contracts normally include funds for related engineering and technical support services as well as for the required hardware items. These additional costs are often reflected in the sole source baseline but are missing from competitive contracts, since they are often funded under a separate contract with the developer. Thus, an apples and oranges problem exists when extrapolating a sole source contract cost that includes services in addition to hardware and comparing the result to competitive contracts for hardware only.

Claims against the government filed and won by disgruntled second sources are another nonrecurring cost element. In effect, some means of implementing competition have provided second sources with an insurance policy. Specifically, second sources may recover overruns caused by optimistic fixed price bids by blaming an allegedly defective technical data package. There is no systematic procedure for tracking and recording such claims. But they are a nonrecurring cost of competition.

Data are also subject to different interpretations. For example, the lot at which competition began may be an issue. There is disagreement about whether competition for the Sparrow AIM-7F Missile began at Lot 3 or Lot 5 (i.e., whether it began when Raytheon--the initial source--expected it to or when General Dynamics actually bid for a competitive quantity). The Lot 3 assumption indicates an estimated savings while the Lot 5 assumption shows a higher cost as a result of competition.

In addition to the identification and interpretation of data, methodologies for making required economic adjustments are also subject to error. Most analysts agree that a suitable discount rate is appropriate for reflecting the time value of money. Yet even skilled practitioners have had difficulty applying this principle. For example, a recent DoD Inspector General report

stated: "Adjustments should be made for the time value of money because several years may elapse between the time 'up front' investments are made and the time when the second source can effectively compete." [1] Yet in adjusting for the time value of money, they used a 10% factor rather than a rate to assess costs of several competitive programs. This failure to apply its stipulated methodology correctly caused a substantial understatement of nonrecurring costs. [1]

The treatment of low rate initial production (LRIP) units for the sole source has also caused problems. Second source LRIP usually constitutes an educational buy. The difference between that price and the current sole source price for the same quantity is treated as either a debit or credit in calculating nonrecurring costs. Specifically, are these costs part of development cost or should they be incorporated into the learning curve? A reasonable convention is to count them as production units if they were produced by hard tooling or if they became operational, as opposed to test, units. This is more than an academic issue, because those units are often relatively expensive and, as a consequence, their omission may significantly change the sole source cost profile.

3. PROBLEMS WITH ESTIMATING SOLE SOURCE RECURRING PRODUCTION COSTS

The Baseline

The Institute for Defense Analysis developed the baseline methodology for estimating the effects of competition on recurring production costs in 1974 [2]. This methodology consists of extrapolating the sole source learning curve as the basis for estimating the sole source cost for producing the entire competitive quantity. The difference between the actual and estimated costs is attributed to competition as either an added cost or savings.

This methodology is commendable for its simplicity which allows competitive programs with more than one initial sole source lot to be measured by the same yardstick. But this

simplicity has exposed it to criticism that its results are misleading because it neglects important factors.

Many factors influence the slope of learning curves. They include, among others: changes in production rate, tooling, capital equipment and facilities, and product design as well as management strategy. However, learning curves conceal the individual effects of these factors by lumping them all together.

Critics of the baseline methodology have focused primarily on three issues that bias or limit the resulting estimates. They are:

- The sole source curve may reflect management's response to an impending competition. Therefore, it does not accurately indicate what its behavior would have been without a competitive threat. For example, management may have elected to charge a higher price to skim greater profits by exploiting its transient monopoly position, or it may have set a lower price to deter the creation of a competitor. In the vast majority of competitive cases with more than two sole source lots, the final sole source point has been substantially below the learning curve slope. This means that the sole source baseline for the competitive estimate is often above the last sole source buy, i.e., it is assumed that the initial competitive buy will be at a higher price than the final sole source buy. Thus, the baseline model has often provided higher estimates of competitive savings than logic would support. However, there is no generally acceptable way of statistically weighting that one particular data point.

- Sole source learning curves based upon price may mask important shifts in cost and/or profit. For example, extrapolating a learning curve that incorporated significant profit reductions or increases between the first and second lots implies that profit would continue to shrink or grow steadily as quantity increased. This is, of course, an

improbable outcome.

- Learning curves do not treat production rate effects explicitly. Therefore, a significant rate increase or decrease during competition could cause related price changes by the initial source to be wrongly attributed to competition.

Alternative Methods

Alternative analytical methods have been employed to correct these problems. But they have faults of their own, some of which are discussed below.

Sole source learning curves based on cost instead of price seek to avoid problems caused by significant profit shifts at the beginning of a program. While such curves give a more accurate picture of initial source behavior regarding cost, they omit consideration of a key factor related to competition: management decisions about acceptable/achievable profit levels. Additionally, cost data (exclusive of profit) are often unattainable which, thereby, causes this methodology to impede interprogram comparisons.

Another alternative methodology constrains the sole source to customary and reasonable values for learning curve or production rate slopes. This is done to obtain a sole source estimate devoid of competitive strategies. However, such a wide range of values comprise industry norms that a "typical value" may be significantly too high or too low for a given case. Thus, prescription of incorrect values could misstate the magnitude or even the direction of the competitive effect.

Several variations of another alternative methodology treat production rate as an independent variable to eliminate the annual cost effects of production build-ups or slow-downs. The idea is that dramatic rate shifts may mask the effects of competition on price. Difficulty in obtaining accurate data is a fundamental problem with this methodology. Annual procurement quantities commonly serve as proxies for production rate because they are easier to obtain than

data related to annual deliveries. But the two may vary significantly. Furthermore, adept scheduling has avoided dramatic rate variances implied by large shifts in annual procurement quantities.

Accurate annual quantity data are necessary but not sufficient to determine rate effects on cost. Product-oriented plants that produce unique end items (e.g., assembly of Sparrow missiles) may have different optimal production rates (i.e., Raytheon could be more efficient at a higher or lower rate than General Dynamics). In other cases, cost effects attributed to rate may be due to other activities at the plant (e.g., Raytheon's production cost for Sparrow might increase or decrease in accordance with production rates for Phoenix, SM-2, Sidewinder, and Maverick).

Thus, effects of production rate on competitive costs may be more apparent than real. They may even lead to self-fulfilling prophecies. Consider the following example where initial source excess capacity leads to "competitive savings:"

> *Firm A has special tooling and test equipment sufficient for producing* 1000 units per year. A subsequent program budget reduction limits it to 600 units per year. Its costs are higher than estimated. The government establishes Firm B as a second source to produce up to 60 percent of the new annual quantity (360 units per year). B submits a lower bid than A for the initial split-buy because its tooling is appropriate for the new rate (i.e., 360 vs. 1000 units per year). The government classifies this as another competitive cost saving.

All of the alternative methodologies introduce problems of their own into the analytical process. Moreover, there is one problem common to all methodologies. They focus on individual programs.

A Common Problem

No methodology has been developed that looks at the causes of competitive behavior and the effects of competition above the individual program level: specifically, how have firms managed their mix of programs to achieve optimal returns, and how have broader economic conditions have affected competitiveness?

Competition has expanded the focus of defense industry management to consider overall profitability as opposed to the welfare of individual fiefdoms. Now, decision makers for competitive bids more often consider the effect of a program on amortizing fixed overhead and, therefore, increasing the profitability of programs already in-house. They also weigh technical synergy with other programs or new business growth targets.

A down side to this greater management perspective is the shifting of costs to "protected programs." Black programs have grown substantially since the expansion of competition, and anecdotes about their relatively high overheads abound. Without a systematic analysis of the effects of competitive programs on a contractor's total business it is impossible to determine how the government has fared overall.

Survival is an even more compelling incentive than strategy. Some analysts have suggested the importance of industry capacity in determining competitiveness. This factor is evident in shipbuilding where excess industry capacity has combined with competition to generate dramatic projected savings. Management's choice has been clear: bid at a loss and hope to recover through subsequent changes or go out of business. And competitive savings are projected based upon fixed price incentive contracts. These savings may disappear if the government's ultimate choice is between causing a contractor to file for bankruptcy or terminating it for default rather than paying a higher price.

4. CONCLUSIONS

It is important to put objections to the baseline and alternative analytical methodologies into the proper perspective. Each has its faults. But when used appropriately and their results are interpreted with restraint, important insights about the "what, how, and why" of competitive cases follow. Still, single point estimates of added costs or savings attributed to competition should receive little confidence.

Furthermore, our inability to estimate the economic effects of competition with confidence implies that models which purport to forecast the economic benefits of competition must address this fundamental estimation uncertainty. A number of important variables are not captured by the usual historical data. If these are absent in a predictive model, then they limit its validity.

All the issues raised above notwithstanding, the push toward joint ventured or teamed development programs leading to production competition has changed the nature of the baseline methodology in at least two important respects:

- The "perfect information" gained by involvement in a program from the beginning should eliminate the occurrence of bids by an "ignorant" second source that typically have provided "competitive savings."
- When two firms are involved in a development, it is not clear how their learning curves would compare with a "typical" sole source curve.

Thus, the rules of the game have changed so significantly that even accurate estimates of the economic effects of "typical dual source competition" may not be relevant for current acquisition strategies.

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DUAL SOURCING AS AN ACQUISITION STRATEGY

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This paper is extracted from Karen W. Tyson, et al., *Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness*, IDA Paper P-2201, March 1989 [20].

1. BACKGROUND

Defense acquisition has a long history of competition. The Armed Services Procurement Act of 1947 required that contracts for property or services be formally advertised. OMB Circular A-109 directs that competition be used throughout a program, particularly during design and development. Competition at that point has the advantage of allowing the exploration of different alternatives. Competition often has been used in full-scale development. More recently, however, the government has emphasized competition in production, the explicit goal being lower prices and, possibly, better performance.

In the 1980s, Congress prescribed production competition. In the Defense Appropriations Act of 1984, Congress required that any major acquisition program have either a certification that the system would be procured in insufficient quantities to warrant multiple sourcing or a plan for the development of two or more sources. The Competition in Contracting Act of 1984 established requirements for maximizing competition. Competition was to be the norm; exceptions were to be justified. CICA required the appointment of competition advocates to review acquisition strategies. Additional legislation--the Department of Defense Procurement Reform Act and the

Small Business and Federal Procurement Competition Enhancement Act of 1984 and the Defense Procurement Improvement Act of 1985--also aimed to increase competition in defense contracting.

In addition, the Defense Department has encouraged competition. The Defense Acquisition Improvement Program (the Carlucci Initiatives), instituted in 1981, includes an initiative to increase competition in the acquisition process. In 1984, the Defense Systems Management College (DSMC) published a handbook for program managers on enhancing competition [1].

Competition has a number of applications in defense procurement. The types of items that the government buys can be visualized along a continuum with respect to quantity and complexity. Small, uncomplicated items that the government buys a lot of over the years are easy to compete. In many cases, these items are standardized, and it is relatively easy to obtain multiple sources. At the other end of the continuum, major weapons systems are developed on a customized basis and produced in relatively small numbers. A company that wants to produce Sidewinder missiles cannot merely do some quick tooling and start producing them--a detailed technical data package is needed.

In this paper, dual sourcing in production for major weapon systems and subsystems is addressed. This type of competition typically requires that the government have a hand in developing an alternative source, just as it developed the first source. Other methods of enhancing competition in major weapons systems, including vendor competition, are not discussed here. After some preliminary points concerning competition and the competitive environment, empirical results from several analyses are further analyzed and discussed.

2. BENEFITS AND WEAKNESSES

In the short term, the benefits of dual-source competition in major systems might be expected to include:

- Lower overall costs
- Increased contractor responsiveness to government needs
- Enhanced system quality and reliability, put in as an attractive feature for government purchasers. (A number of competition programs, including Tomahawk and the alternative fighter engine, were motivated more by quality considerations than by cost.)

Longer-term benefits could include:

- Enhanced industrial base for particular systems
- Increased capital investment by contractors.

In the short term, the weaknesses of competition include additional costs in areas not found in single-source production:

- Competition typically requires an up-front investment for tooling, equipment, qualification, and administration to establish a second source.
- By splitting a buy between two contractors, the government may give up some economies of scale because the full benefits of learning and high-rate production are not realized. Large buys typically exhibit lower unit costs than small buys.
- If multiple configurations are required, support costs may increase.

There may be long-term weaknesses of competition with respect to the relationships between industry and the Department of Defense, but little attention has been paid these issues. Are the benefits of competition a one-time effect, or can they be sustained over time? Production competition in major systems must be viewed as an investment decision. The potential reduction in procurement costs must be weighed against additional up-front costs and increased government administrative costs. This tradeoff is unique for each program.

The DSMC program managers' handbook indicates a method for evaluating the impact of production-level competition on program costs. In evaluating potential or actual cases of competition, analysts may find these guidelines useful [1, pp. 7-1, 7-2]:

(1) Estimate single source recurring production costs by fiscal year in constant dollars based upon progress curves and expressed as contractor price.

(2) Estimate competitive recurring production costs by fiscal year in constant dollars based upon progress curves. Reasonable assumptions must be made concerning shift and rotation and the second source progress curve.

(3) Calculate potential savings by subtracting (2) from (1) by fiscal year.

(4) Calculate net potential savings by subtracting annual incremental government costs, stated in constant dollars, from (3).

(5) Estimate nonrecurring start-up costs, stated in constant dollars, by fiscal year.

(6) Estimate incremental logistic support costs, stated in constant dollars. by fiscal year.

(7) Calculate a net present value of competitive versus sole source production costs by subtracting the discounted costs (5) and (6) from the discounted benefits (3).

(8) Compare discounted, constant, and then-year dollar estimates of single source and competitive production.

(9) Conduct detailed sensitivity analyses to investigate the effect of changes in key assumptions on the estimate of savings, and to develop a range of likely estimates.

3. TYPICAL APPLICATION

Competition can be applied in a variety of ways--so many that it is difficult to talk of a "typical" application. The examples that follow show that variety:

- In the sea-launched cruise missile (SLCM) program, the government required the contractors to fund the costs of technology transfer, but allowed them to charge back the amount at the rate of 1/1200 of the total cost for each of the first 1,500 missiles (*more* than they invested). However, the competition provided the contractors with a powerful incentive not to charge the full amount allowed.
- In the F100/110 alternative fighter engine program, the government funded the costs of bringing a partially developed engine to full capability. In the F404 engine competition, the government delivered an engine developed by one contractor for reverse engineering by another. The government and the second contractor made some up-front investment.
- In the High-Speed Antiradiation Missile (HARM) program, the government had a detailed technical data package from the first source, and three potential competitors invested in developing competing manufacturing methods for the design. (This program remained sole source.)
- In the Maverick missile program, the competition had a leader and a follower.

Government funding of the second source is common, as is the use of "educational buys" or "qualification buys" to get the second source started. Another common factor is the use of annual competitive bids between contractors. Typically, in major systems, these annual competitions are not winner-take-all, but the buy is split between the contractors. This practice can cause the government some problems in fine-tuning its approach: the government must give the winner enough of a "reward" to encourage future low bids, but it must give the loser a large enough order to keep its production line going. Depending on how its bid is structured, a clever loser might end up with more profits than a winner.

4. CASES EXAMINED

To examine the evidence on competition, information was gathered on several programs from studies on competition by IDA, Rand, and the services (particularly the Navy) [2 through 20]. Among the competitive programs included in the review are the F100/110 and the F404 alternative fighter engines and the following missiles: Imaging Infrared (IIR) Maverick AGM-65D/F/G, Tomahawk ground-launched cruise missile (GLCM), Sparrow AIM-7F and AIM-7M, HARM, Hellfire, TOW (tube-launched, optically tracked, wire-guided), Sidewinder AIM-9L and AIM-9M, Phoenix, basic Stinger, Shillelagh, and Dragon. The analysis of the data gathered is described in the next section.

5. ANALYSIS

Depending on the appropriateness and availability of data, the following analyses were conducted:

- Analysis of data on price and quantity, on the number of competitive years, and on the startup costs of the competition
- Analysis of the costs and benefits of competition
- Analysis of cost and schedule outcomes of 64 major programs, of which 13 are competitive.

The examination of individual cases yielded the following results:

- In the F100/110 alternative fighter engine competition, the evidence on savings is confounded by a model change. However, since a model change (which normally is costly) was achieved without a statistically significant increase in price, a reasonable interpretation is that competition has had a favorable impact on unit prices. In the F404 engine, savings of $125 million to $300 million were

found in the analysis.

- In the IIR Maverick program, competition has so far resulted in increased costs. However, it is possible that the government will achieve savings if it continues to acquire these missiles through FY 1997 as planned.
- In the Sparrow AIM-7F program, other research (including an independent evaluation of work by the Naval Center for Cost Analysis (NCA) [2, 6]) found no evidence of savings. Independent analysis described further in [20] also found no evidence of savings.
- In the Tomahawk missile program, both the program office and the NCA show cost savings over sole source.
- In the HARM program, lower prices from the threat of competition resulted in a decision not to dual source. The incumbent, Texas Instruments, dropped its price by $209 million for the period FY 1983-85 and by $1.2 billion for the period FY 1983-89 in order to stay sole source [8].
- In the Hellfire program, there is no evidence of savings from competition. However, a second source was established at no apparent cost to the government [19].

In addition to the case studies, several studies of dual-sourced programs were reviewed. The results of this review are summarized below:

- Berg, et al. [7] found an unclear picture with respect to the Sparrow AIM-7F competition as to whether there were savings or not. They found no savings in the Sidewinder AIM-9L competition, but savings of about 11-12 percent were found in the AIM-9M competition.
- The behavioral aspects of competition--the effects of competition on the

way contractors do business--are very important. Relatively few sources discuss these aspects of company strategy. Greer and Liao [17] cite three alternative strategies a firm may pursue in response to competition. These include:

- Constant percentage profit
- Penetration pricing--first source sets price low enough to discourage competition
- Skimming price--company sets a high price and lowers it as necessary to meet competition.

- Greer and Liao use industry capacity utilization as a measure of what strategy companies are likely to follow. If capacity utilization is high, then firms are busy and are unlikely to lower prices very far to get work. However, if capacity utilization is low, firms are willing to be very flexible about price in order to keep working. More analysis of this type is warranted.
- In 1987, the NCA examined eight cases of competition for cost savings [2]. They found that five of the eight programs (Sidewinder AIM-9L, armored box launcher, CG-47 cruiser, LSD-41 landing ship dock, and Mk 182-1 chaff cartridge) had associated net price savings, or at worst, an approximate breakeven. Net savings estimates ranged from 4 to 24 percent of estimated total sole-source price. Two programs (Mk 46 Mod 1 and AIM-9M) had a net price loss. AIM-7F had savings if Lot 3 is the assumed start of competition, but a loss if Lot 5 is the assumed start.
- Berg, Jondrow, and Pisani [3] used a pooled sample of 18 missile programs over the period 1970-84. They found that competition had a negative effect on cost, but it was not generally statistically significant.

- A study of financial strength as a predictor of pricing strategy (Webb [14]) found that a significant portion of the variance in the price-reduction curve could be explained by the firm's financial condition measured against industry averages. While Webb was looking primarily at sole-source programs or at vendors, the results are interesting to contemplate in the light of competitive strategies. Firms that are investing most heavily in new plants and equipment are motivated to adopt market penetration strategies (e.g., work to build market share) to ensure that their capacity will be used. Firms with poor liquidity will prefer profits in the near term and may go after small but profitable pieces of the market. For example, McDonnell Douglas built the Titusville plant exclusively for Tomahawk missile production, and they have bid aggressively to win quantity. Conversely, Raytheon seems to be becoming a specialist in being a follower, a production specialist.

6. RESULTS

Regression analysis of competitive and non-competitive programs indicated no statistically significant difference in cost growth between competitive and non-competitive equipment types [20]. Table 1 shows results from the aggregate analysis. An analysis of averages from the full sample and from the group of tactical munitions (where virtually all the competition in the group of programs examined has occurred) is interesting. In the full sample, cost growth under competition is higher. However, cost growth under competition is lower among the tactical munitions, where most of the competition has occurred.

In both cases, production quantity growth is much higher in the competitive programs, and program stretch is much lower. Possible explanations are that stable programs are chosen for

competition, or that the government keeps competitive programs more stable, given its up-front investment to dual source.

Table 1. Comparison of Outcomes for Competitive and Non-Competitive Programs

	Full Sample		Tactical Munitions	
	Competitive (N = 13)	Non-Competitive (N = 51)	Competitive (N = 11)	Non-Competitive (N = 17)
TPCG (TPCG = Total Program Cost Growth)	1.74 (12)	1.49	1.78	2.16 (16)
PCG (PCG = Production Cost Growth)	1.78 (12)	1.64	1.82	2.46 (16)
PQG (PQG = Production Quantity Growth)	1.90 (12)	1.06	1.74	0.78 (16)
PSG (PSG = Production Schedule Growth)	2.12 (12)	1.53 (45)	2.19	1.60 (15)
Stretch (Stretch = Total Program Stretchout)	1.65 (12)	2.01[a] (44)	1.76	3.15[a] (15)
PS (PS = Production Schedule)	129.0 (12)	126.6 (44)	131.2	117.1 (15)
TS (TS = Total Schedule)	193.6 (12)	167.4 (43)	193.0	169.6 (15)
DCG (DCG = Development Cost Growth)	1.77	1.24 (55)	1.88	1.42
DSG (DSG = Development Schedule Growth)	1.81	1.27 (56)	1.89	1.42
CS (CS = Concurrent Schedule)	34.5	32.2 (49)	34.1	30.4

[a]Condor (stretch = 56) excluded.

Notes: The competitive tactical munitions programs are TOW, Hellfire, Sparrow AIM-7F and AIM-7M, Sidewinder AIM-9L and AIM-9M, Maverick AGM-65D, Phoenix AIM-54A and AIM-54C, Basic Stinger, Shillelagh, and Dragon. The only competitive programs in the database that were not tactical munitions were the electronic systems SINCGARS (which had only development information) and the cruise missile Tomahawk. Cost growth figures are dollar-weighted. Figures in parentheses are numbers of programs for cells with missing data.

7. FINDINGS AND CONCLUSIONS

The findings of the analyses of competition programs are summarized below:

- In missile programs, cost growth in competitive programs was lower than in non-competitive programs. While this difference was not statistically significant, it suggests that competition may be beneficial.
- Findings about competition in the case studies are sensitive to assumptions about what prices would have been if the program had remained sole source. The literature on cost savings is contradictory.
- It is easier to find savings in prices than in costs. Several studies evaluating costs such as engineering hours and manufacturing hours find similar direct costs in competitive and sole-source programs. Thus, savings from competition seem to come out of profits, as theory would expect. It makes sense to look for savings in programs where profits have historically been high.
- Competitive programs tend to buy more quantity than planned over a longer period of time than planned. This tends to amortize development costs and second-source startup costs. It may be that the benefits seen from competition are really benefits of program stability--this is a chicken-egg problem.
- Cross-program effects and industry strategies have been insufficiently analyzed. Even if the government observes savings from competition, it also needs to examine whether there are cost increases in sole-source programs produced in the same plant. Also, in some programs, such as Hellfire, a seesaw pattern of production was observed, with the companies alternating winning the major share of the year's production. This might allow the contractors to plan stable production rates. One-time gains may be possible as competition

represents a shock to the system--it is unclear that such gains can be sustained if competition becomes a universal acquisition strategy.

- That cost savings from competition are uncertain should be recognized. It does not make sense to plan on large, immediate cost savings. Competition requires some up-front investment, and payback is over a number of years.
- Specific guidelines should be established for competition, similar to those for multi-year procurement.
- Additional research should be done into the long-term effects of competition. Such research should go beyond the individual program to consider overall contractor strategies.

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RESULTS OF COMPETITIVE PROCUREMENTS OF NAVY WEAPON SYSTEMS IN THE 1980's

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1. INTRODUCTION

Since the Competition in Contracting Act of 1984, Navy and DoD policy has been to compete major weapon systems. Cost analyses of competitive procurement at the time of the Act were often based on different interpretations of Sparrow AIM-7F competition [1] and on ad hoc shifts and rotations of the sole-source learning curve. Over the last few years, however, the Navy has awarded many contracts competitively, usually on a fixed-priced basis, for ships, missiles, torpedoes, and other weapon systems. Indeed, sole-source procurement of major weapon systems over the past few years has been the exception rather than the rule.

The Naval Center for Cost Analysis (NCA) has gathered data on the results of competitive procurement of some of these systems for use in performing independent cost estimates and in analyzing acquisition strategies. While it is impossible to accurately and consistently predict the behavior of a firm's unit price under competition, reasonable estimates of overall program savings or losses based on recent Navy experience nevertheless are possible.

This study presents results of competitive procurement of twelve Navy weapon systems using price level data. Descriptive statistics are presented showing estimated savings and unit

price changes under competition. Detailed analyses of each of the twelve cases is found in NCA's technical report entitled *Analysis of Competitive Procurement of Selected Navy Weapon Systems, Second Edition* [2].

It is anticipated that NCA will use this database along with other information to build a model for estimating the savings from competitive procurement.

2. METHODOLOGY

The savings from competitive procurement were estimated using the formula:

Savings = Projected Sole-Source Costs **minus**

[Projected Competitive Costs **plus** Second-Source Start-Up Costs],

where each term on the right-hand side is defined as follows:

a. Projected Sole-Source Costs: Sole-source learning curves were estimated at the price level for eleven of the twelve systems using contract actuals or estimates at completion. For the MK-48 Advanced Capability (ADCAP) torpedo, a Cost Estimating Relationship (CER) was used to generate the sole-source curve.

b. Projected Competitive Costs: Learning curves for each company for outyear awards were usually based on sole-source slopes fitted through that firm's last unit price. These estimates, then, assume the absence of any further cost savings due to competition.

c. Second-Source Start-Up Costs: These are costs incurred by the government. Excluded are any costs that a firm has chosen to absorb to win the competition to become second-source. These costs include:

1. Technology Transfer--Includes contracts to the initial and second sources for transferring technical knowledge.

2. Qualification Units--Includes hardware fabrication and testing.

3. Government Support--Includes the cost of field activities and support contractors to the program office.

4. Special Tooling and Test Equipment--Includes tooling and equipment unique to the program for which it is procured.

Another measure of the saving from competitive procurement, the percentage savings, is calculated using the following formula:

Percentage savings = Savings **divided by** [Projected Sole Source Cost] ,

where the savings is calculated on either a recurring or a net basis.

This methodology excludes the following items which are difficult to measure yet nevertheless are relevant in assessing the overall impact of competition:

a. Added Government Personnel: Additional contracting and program-office personnel are required to establish a second-source producer. However, less manpower may be required once competition begins since contracts are usually awarded based simply on step-ladder quotes rather than on lengthy sole-source negotiations. Hence, the net effect of this term on competition savings is unclear.

b. Transfer of the Firm 's Personnel to Other Projects: A firm may unload engineering personnel from the program being competed to one that is sole-source, thereby increasing the cost of the latter and decreasing the true, as opposed to the apparent, magnitude of savings from competition.

c. Value of Engineering Labor: When a firm cuts engineering labor hours under the pressure of competitive bidding, the Navy may be losing the services of personnel on the periphery of the program who were advancing the state of the art in weapon system technology. This loss represents a cost of competition.

d. Changes in Hardware Quality: Quality could either improve or diminish under competition. It might improve as a firm is forced by its opponent to develop new and better production processes. It might decrease as a firm cuts quality assurance hours. The cost of quality changes is therefore unclear.

3. RESULTS OF THE ANALYSIS

This section summarizes the results of the analysis of the twelve competitive procurements. The first section presents estimates of savings or losses, the second briefly explains results of each acquisition, and the third shows changes in unit price by each firm under competition.

Estimated Savings

Figure 1 shows the estimated percentage return from competition for each system. Calculations are made from the time second-sourcing began for each system through FY94, with all values in FY89 constant dollars. Figure 2 shows the estimated return in dollar rather than percentage terms. Table 1 presents numerical results, while Table 2 presents estimated savings through only FY89. The following discussion is based on Figures 1 and 2 and Table 1, since these represent reasonable lifetime projections for the weapon systems under consideration.

It can be seen that estimated net savings are $4.4 billion in FY89$ out of total projected sole-source costs of $30.9 billion, or 14.2%. Estimated savings on recurring prices are 16.6% of projected sole-source costs. Estimated second-source start-up costs are 2.4% of projected sole-source costs.

Of the three programs with the highest percentage net savings, two are ships: CG-47 and LSD-41. However, not all ship programs enjoy above average savings as the TAO-187 competition indicates.

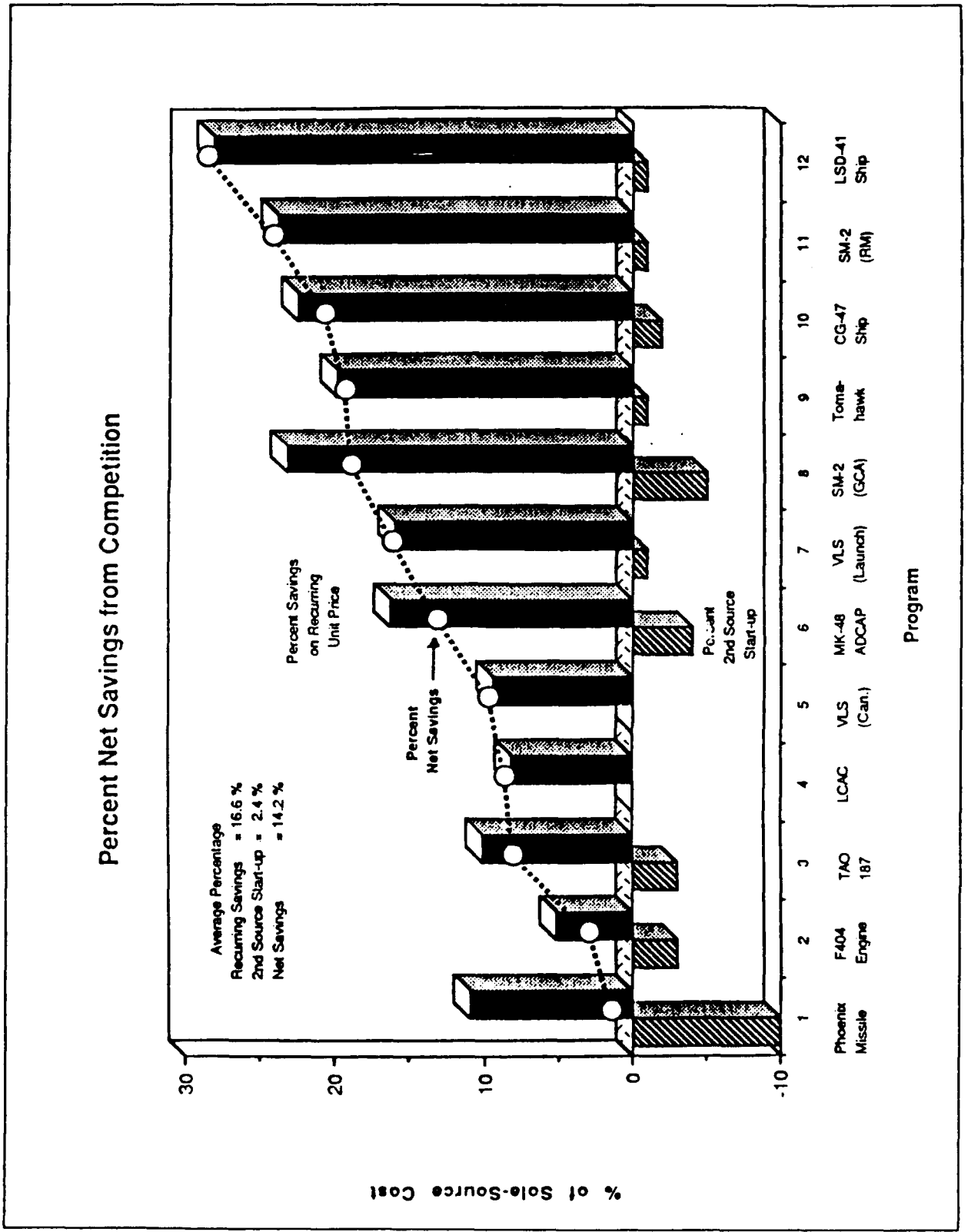

Percent Net Savings from Competition
Average Percentage
Recurring Savings = 16.6 %
2nd Source Start-up = 2.4 %
Net Savings = 14.2 %
Percent Savings on Recurring Unit Price
Percent Net Savings
Percent 2nd Source Start-up
% of Sole-Source Cost
30
20
10
0
-10
1 Phoenix Missile
2 F404 Engine
3 TAO 187
4 LCAC
5 VLS (Can.)
6 MK-48 ADCAP
7 VLS (Launch)
8 SM-2 (GCA)
9 Toma-hawk
10 CG-47 Ship
11 SM-2 (RM)
12 LSD-41 Ship
Program

Figure 1

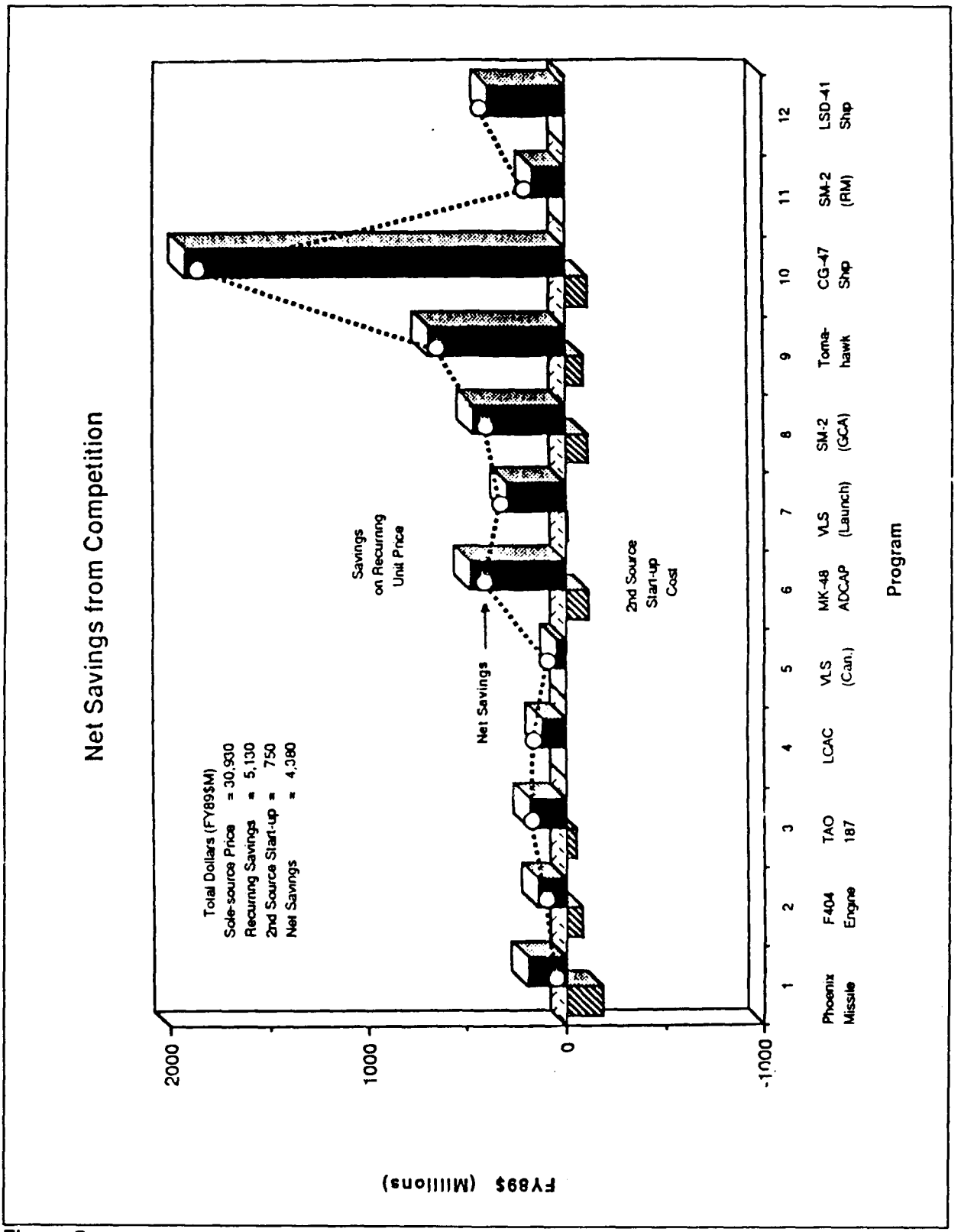

Net Savings from Competition
Total Dollars (FY89$M)
Sole-source Price = 30,930
Recurring Savings = 5,130
2nd Source Start-up = 750
Net Savings = 4,380
Savings on Recurring Unit Price
Net Savings
2nd Source Start-up Cost
FY89$ (Millions)
2000
1000
0
-1000
1 Phoenix Missile
2 F404 Engine
3 TAO 187
4 LCAC
5 VLS (Can.)
6 MK-48 ADCAP
7 VLS (Launch)
8 SM-2 (GCA)
9 Tomahawk
10 CG-47 Ship
11 SM-2 (RM)
12 LSD-41 Ship
Program

Figure 2

Table 1
Estimated Savings from Competition Through FY94
In Millions of FY89$ and Percent of Sole-Source Cost

	Sole-Source Cost	2nd Source Start-up Cost		Recurring Savings		Net Savings	
Phoenix	1,804	183	10.1%	198	11.0%	15	0.8%
F404 Engines	2,885	82	2.8%	148	5.1%	66	2.3%
TAO-187 Ships	1,822	47	2.6%	182	10.1%	135	7.4%
LCAC's	1,560	3	0.2%	128	8.2%	125	8.0%
VLS Canisters	540	2	0.3%	51	9.4%	49	9.1%
MK-48 Torpedo	2,978	109	3.7%	484	16.3%	375	12.6%
VLS Launchers	1,831	9	0.5%	295	16.1%	286	15.6%
SM-2 GC&A	2,264	109	4.8%	466	20.6%	357	15.8%
Tomahawk	3,345	88	2.6%	692	20.7%	604	18.1%
CG-47 Ships	9,800	111	1.1%	1921	19.6%	1810	18.5%
SM-2 Rkt Motor	711	3	0.4%	170	23.9%	168	23.6%
LSD-41 Ships	1,393	5	0.4%	394	28.3%	389	27.9%
Total	30,934	751	2.4%	5,129	16.6%	4,380	14.2%

Table 2
Estimated Savings from Competition Through FY89
In Millions of FY89$ and Percent of Sole-Source Cost

	Sole-Source Cost	2nd Source Start-up Cost		Recurring Savings		Net Savings	
Phoenix	667	183	27.4%	60	9.0%	-123	-18.5%
F404 Engines	1,255	82	6.5%	41	3.3%	-41	-3.2%
TAO-187 Ships	1,822	47	2.6%	182	10.0%	135	7.4%
LCAC's	635	3	0.5%	33	5.2%	30	4.7%
VLS Canisters	225	2	0.7%	-8	-3.7%	-10	-4.5%
MK-48 Torpedo	711	109	15.4%	108	15.2%	-1	-0.2%
VLS Launchers	1,052	9	0.9%	141	13.4%	131	12.5%
SM-2 GC&A	1,567	109	7.0%	255	16.3%	146	9.3%
Tomahawk	2,051	88	4.3%	149	7.3%	61	3.0%
CG-47 Ships	9,800	111	1.1%	1921	19.6%	1810	18.5%
SM-2 Rkt Motor	289	3	0.9%	55	19.0%	52	18.1%
LSD-41 Ships	1,393	5	0.4%	394	28.3%	389	27.9%
Total	21,465	751	3.5%	3,330	15.5%	2,579	12.0%

The two programs with the lowest net savings, Phoenix missiles and F404 engines, started competition late with few units remaining to be produced. Starting competition late, however, does not always imply below average savings, as the SM-2 GC&A shows.

In dollar terms, the CG-47 ships program shows the largest net savings by far. It is also the most expensive program with estimated sole-source costs of almost $10 billion.

Program Differences

This section presents some of the reasons for the variance in savings among the 12 systems.

a. Marginal Savings (less than 5%): Phoenix missile and F404 engines. Competition started late in both programs. For Phoenix, more than half of total missile quantity was procured before the start of head-to-head competition. For F404 engines, competition began in Lot 10. Further, the Phoenix missile guidance section is highly complex, much more so than the SM-2's; the number of potential second sources was therefore greatly limited. Similarly, Pratt & Whitney on the F-404 was the only other firm in the U.S. besides General Electric capable of manufacturing the engine. The return on competition for these two programs should be considered a "wash," since estimating error is at least two or three percentage points.

b. Moderate Savings (5 to 10%): TAO-187 ships, LCAC's, and VLS canisters. In each of these acquisitions, either the leader or follower was a vigorous competitor, but never both. On the TAO program, the second source, Penn Ship, underestimated the cost of the job (Block II) and performed badly. This limited their effectiveness in subsequent competitions.

On the LCAC program, competition to become second source for these somewhat unusual craft was limited to two yards. The second source, Avondale Gulfport Marine, has been moderately effective in competing against Textron Marine Systems.

On VLS canisters, the second and third sources, FMC and Israel Military Industries, undercut sole-source prices sharply. But Martin Marietta, the leader, raised their price under competition.

c. Significant Savings (11 to 15%): MK-48 ADCAP, VLS launchers, and SM-2 GC&A. Both leader and follower bid vigorously in each case. Some of the companies made key strategic decisions to put themselves in better positions to win contracts. On MK-48 Advanced Capability torpedo, Hughes changed the location of their fabrication facility from California to Mississippi to be able to compete with Westinghouse, the follower. On VLS launchers, Martin Marietta dropped their sole-source price significantly in reaction to FMC's aggressive behavior.

On SM-2 GC&A sets, General Dynamics/Pomona dropped their unit price 35% in the first year of head-to-head competition, after having been sole-source producer for 20 years. Raytheon, who fabricates GC&A sets in Tennessee, won the second year with an even lower unit price.

d. Large Savings (16% and over): Tomahawk missile, CG-47 ships, SM-2 rocket motor, and LSD-41 ships. Two of the four programs are ships, and shipyards in the U.S. in the 1980's bid on a cut-throat basis because of an almost total absence of commercial business. On CG-47 cruisers, Bath Iron Works badly needed the work as second source because their FFG-7 program was ending. On LSD-41 class ships, hulls 44 to 48 were procured winner-take-all and yielded higher savings than any other case examined.

On Tomahawk missile, the winner of the majority of the production units has fluctuated yearly as General Dynamics/Convair and McDonnell Douglas (MDAC) heatedly compete. MDAC built a missile fabrication facility in Florida to optimize production under second-sourcing.

On SM-2 rocket motor, Morton Thiokol dropped their sole-source price sharply in response to an extraordinarily low price by the follower, Atlantic Research Corp., on directed-buy

units.

4. COMPETITIVE BEHAVIOR OF FIRST AND SECOND SOURCES

Figure 3 shows the average percent change in combined unit price by both contractors (the white circles) in each year of competition, relative to the sole-source price. Table 3 provides individual and aggregate numerical results. Note that only two of the programs analyzed have had a full five years of competition upon which to base the average. The 32% figure, then, should not be regarded as representative of programs, in general.

Figure 3 also shows the percent deltas for winning and losing contractors. The winning firm in any acquisition, of course, may change from year to year. The losing firm in the first four years of competition receives a price slightly above the sole-source projection. This may be due to a refusal to play the competition game for low quantities, increased profit, or diseconomies of scale. The winning firm, on the other hand, is significantly below the sole-source curve.

These results suggest that:

a. Competition intensifies over time as each firm takes the other's measure, and as each learns that it has to continue to lower its price in order to win the bulk of a production lot.

b. The application of rotations to learning curves may be inappropriate in explaining the behavior of prices under competition. Of crucial concern to a firm is its expectation of what the other firm will bid.

Figures 4 and 5 further analyse the data shown in Table 3. Figure 4 graphs the percent change in unit price in the first year of competition for each of the twelve systems. Since these figures are in percentage terms, the combined delta for some programs is only slightly positive while net dollar savings to the Navy turn out to be large.

A good example is Tomahawk. On this program, MDAC started slowly, having initially built

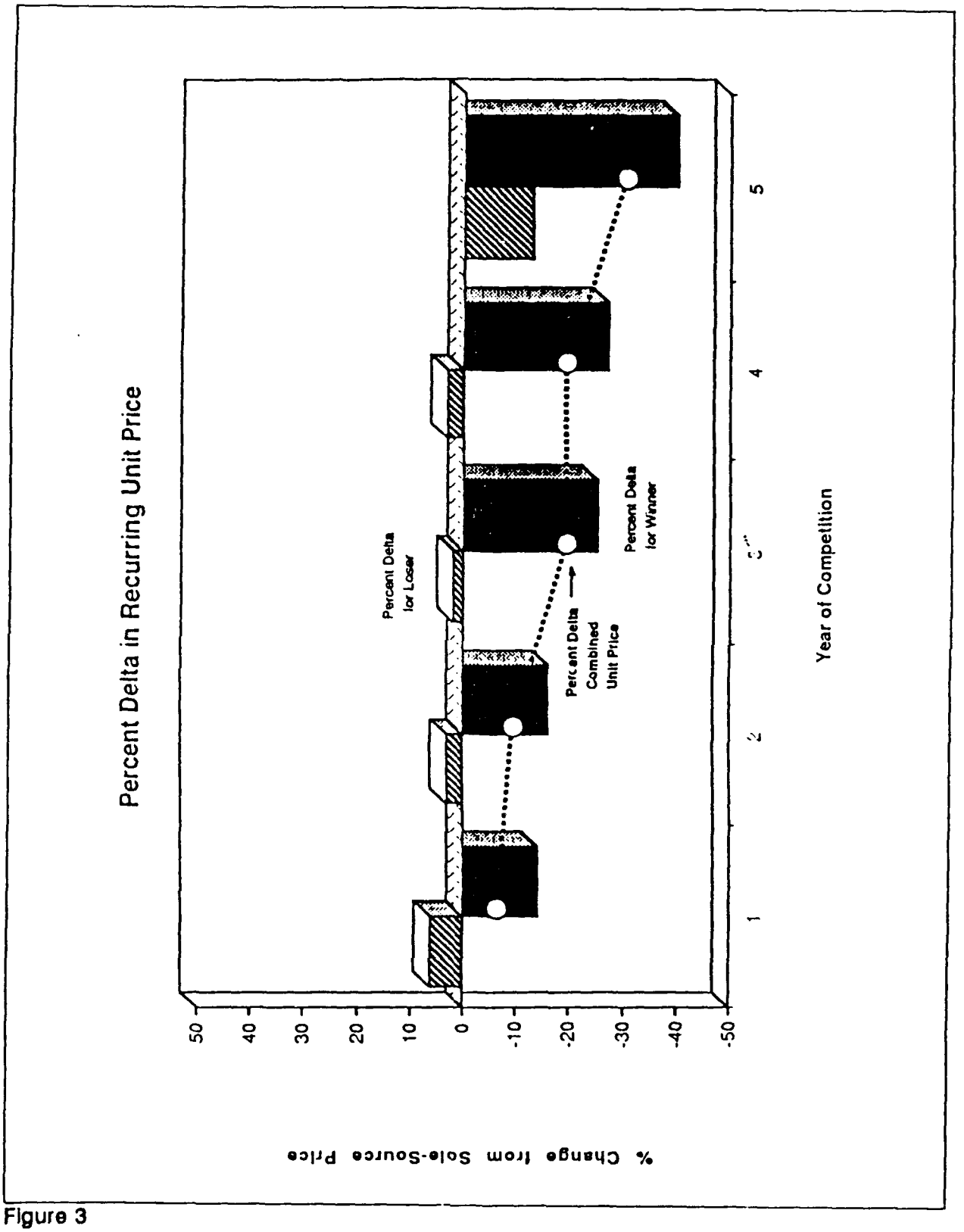

Percent Delta in Recurring Unit Price
% Change from Sole-Source Price
50
40
30
20
10
0
-10
-20
-30
-40
-50
1
2
3
4
5
Year of Competition
Percent Delta for Loser
Percent Delta Combined Unit Price
Percent Delta for Winner

Figure 3

Table 3
Percent Delta in Recurring Unit Price
By Year of Competition

Program	Year 1	Year 2	Year 3	Year 4	Year 5
Phoenix	-15%	(Combined delta listed first)			
Winner	-16%				
Loser	-14%				
F404 Engine	-8%	-6%			
Winner	-14%	-10%			
Loser	7%	6%			
TAO-187 Ships	10%	-15%	-17%	-16%	
Winner	9%	-15%	-17%	-16%	
Loser	10%				
LCAC	-8%	-6%			
Winner	-9%	-9%			
Loser	-7%	9%			
VLS Canisters	21%	40%	-20%	-28%	
Winner	16%	23%	-27%	-35%	
Loser	47%	64%	30%	23%	
MK-48 ADCAP	-19%				
Winner	-21%				
Loser	-16%				
VLS Launchers	-20%	-12%	-19%	-20%	
Winner	-28%	-12%	-22%	-26%	
Loser	20%	-12%	-4%	-7%	
SM-2 GC&A	-31%	-32%			
Winner	-35%	-40%			
Loser	-25%	-20%			
Tomahawk	3%	6%	-16%	-12%	-30%
Winner	-12%	-5%	-24%	-24%	-44%
Loser	26%	22%	-3%	17%	1%
CG-47 Ships	-12%	-23%	-22%	-31%	-35%
Winner	-23%	-26%	-25%	-36%	-36%
Loser	9%	-17%	-17%	-22%	-27%
SM-2 Rocket	-24%	-23%			
Winner	-32%	-32%			
Loser	-3%	-7%			
LSD-41 Ships	-6%	-36%	-34%		
Winner	-6%	-36%	-34%		
Loser	0%				
Average	-9%	-11%	-21%	-21%	-32%
Winner	-14%	-16%	-25%	-27%	-40%
Loser	5%	6%	2%	3%	-13%

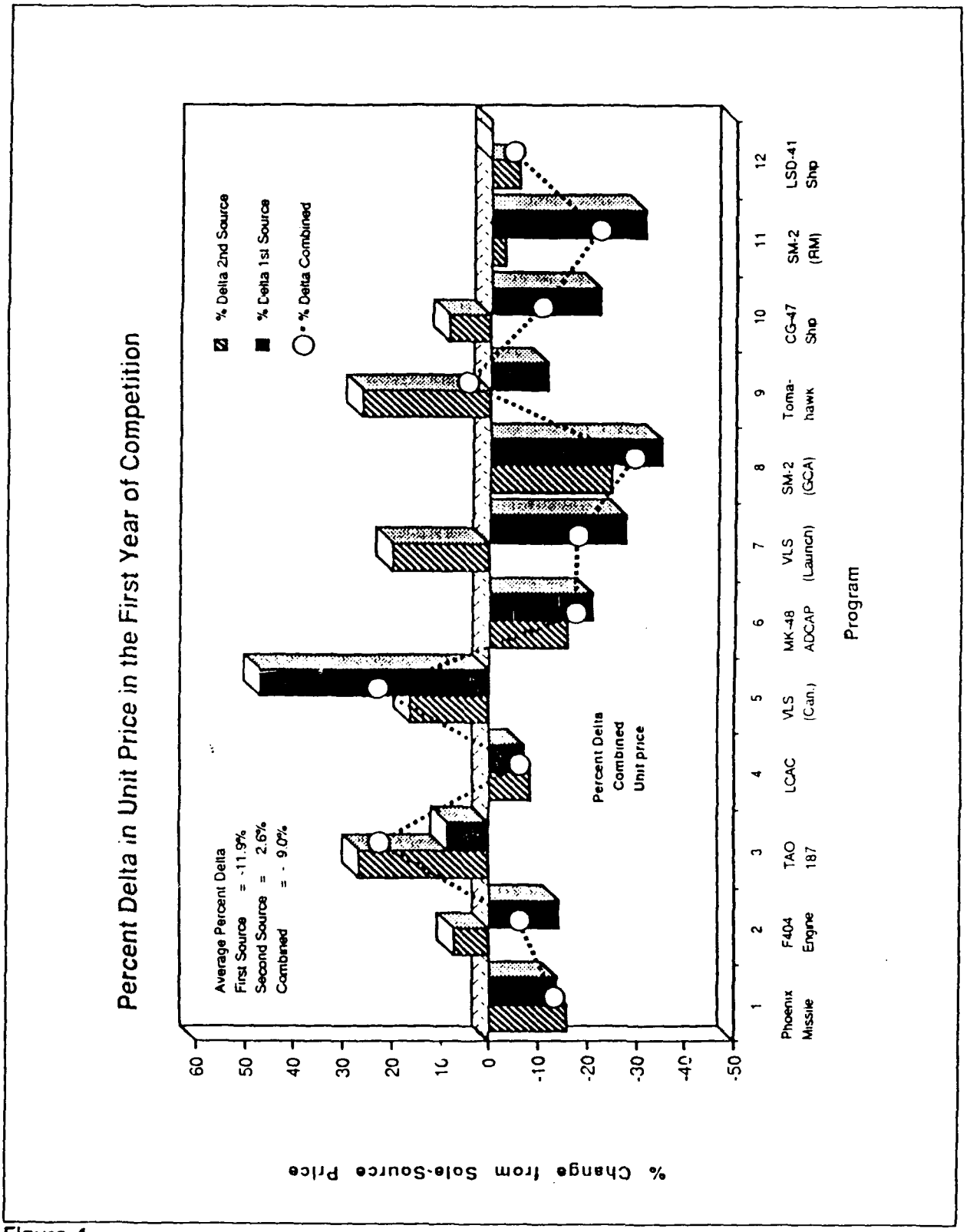
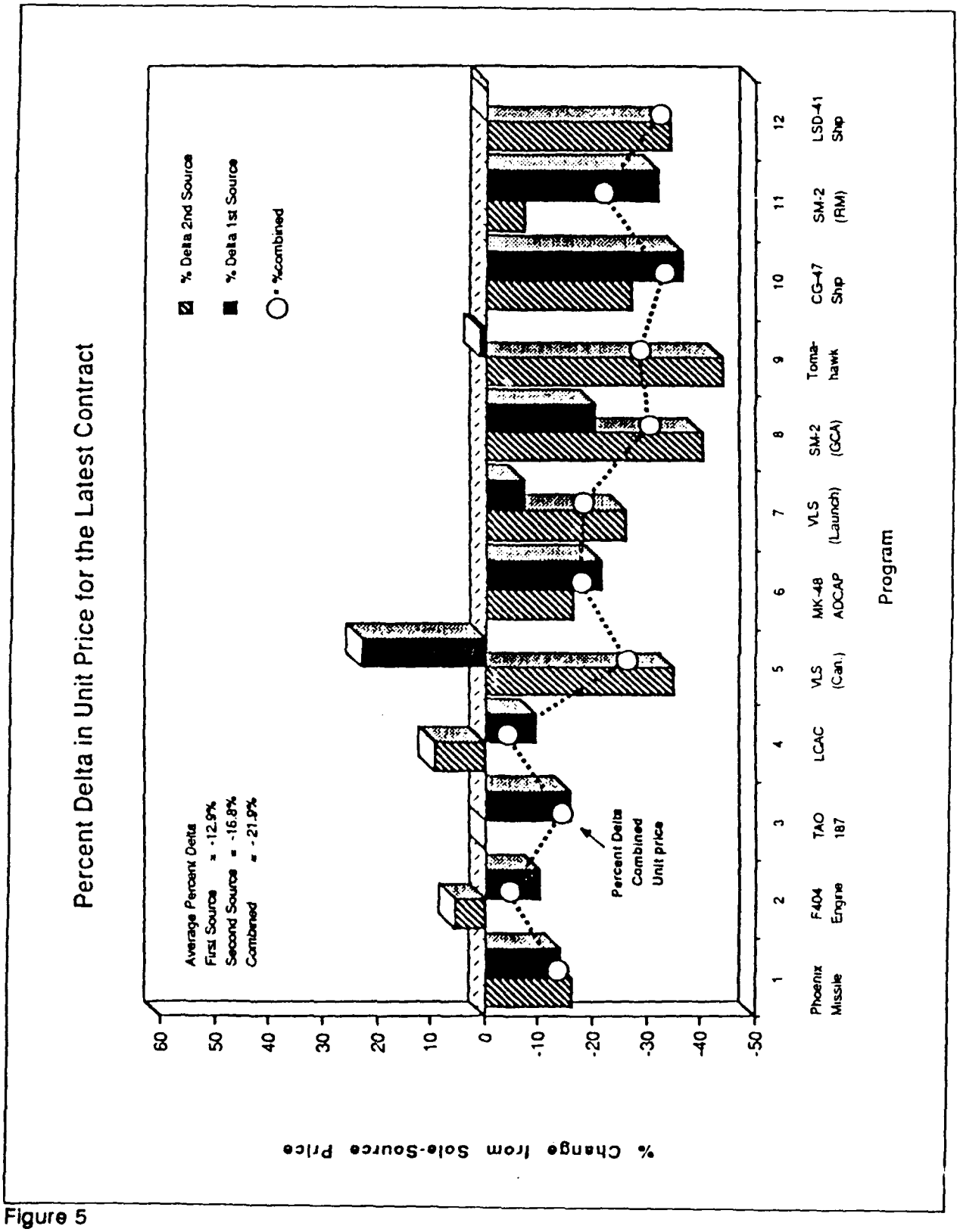

Percent Delta in Unit Price in the First Year of Competition
% Change from Sole-Source Price
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
% Delta 2nd Source
% Delta 1st Source
% Delta Combined
Average Percent Delta
First Source = -11.9%
Second Source = 2.6%
Combined = - 9.0%
Percent Delta
Combined
Unit price
1 Phoenix Missile
2 F404 Engine
3 TAO 187
4 LCAC
5 VLS (Can.)
6 MK-48 ADCAP
7 VLS (Launch)
8 SM-2 (GCA)
9 Toma-hawk
10 CG-47 Ship
11 SM-2 (RM)
12 LSD-41 Ship
Program

Figure 4


Percent Delta in Unit Price for the Latest Contract
% Change from Sole-Source Price
Program
% Delta 2nd Source
% Delta 1st Source
%combined
Average Percent Delta
First Source = -12.9%
Second Source = -16.8%
Combined = -21.9%
Percent Delta
Combined
Unit price
Phoenix Missile
F404 Engine
TAO 187
LCAC
VLS (Can.)
MK-48 ADCAP
VLS (Launch)
SM-2 (GCA)
Toma-hawk
CG-47 Ship
SM-2 (RM)
LSD-41 Ship
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
1
2
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12

Figure 5

the guidance section of the missile which represents about 20 to 25% of total cost. As competition commenced they built a new fabrication facility in Florida to take advantage of lower labor rates and to optimize plant size for expected competitive quantities. Their prices were high in FY85 and FY86, the first two years of competition. Then they sharply lowered price in FY87. General Dynamics responded in kind in FY88. Then MDAC in FY89 dropped their price to over 40% below the sole-source projection, as shown in Figure 5.

Comparing the behavior of initial and second sources in the first year of competition to the last year of competition reveals that:

a. The average delta in recurring unit price for the first source does not change much. It is 12% below sole source the first year and 13% below the last year.

b. However, the average delta for the second-source changes drastically, from 2.6% above sole-source the first year to 16.8% below sole-source the last year. Moreover, in many cases (e.g., Tomahawk), the second-source has become the winner, receiving 70% of the annual buy.

c. The behavior of the second-source determines the magnitude of the savings from competition. When the second-source fails to beat the first-source, savings tend to be small (F404, TAO-187, and LCAC). When the second-source beats the first-source, savings are much larger (SM-2 GC&A, Tomahawk, and LSD-41).

5. CONCLUSIONS

Major conclusions of this study are that:

a. The Navy's program of competitive procurement during the 1980's has reduced unit prices of weapon systems and yielded a positive return on investment. Two of the programs analyzed show essentially zero savings to date while all the others show moderate to large

savings.

b. Under competitive procurement, firms manage to reduce unit prices of weapon systems in ways that the government can not predict. Included are major strategic decisions to relocate fabrication facilities and to build new plants of optimum size for second sourcing.

c. Learning curves are insufficient in explaining changes in unit prices under competition. The pricing strategy of a firm seems much more important, that is, deciding what unit price is needed to beat the opposition.

In summary, while competition worked well in reducing prices and saving money in the 1980's, it is unclear if this will continue in the 1990's. The former procurements occurred during the defense build-up. The latter will occur in a much different environment.

ACKNOWLEDGEMENTS

Several members of the Naval Center for Cost Analysis (NCA) contributed to this effort. Ms. Ranae Pepper analyzed the results of TAO-187 ship competition, a complicated acquisition in which two ships from the second source were transferred back to the Leader. Ms. Pepper also analyzed results of VLS canister competition. Mr. Harold Dagel analyzed the results of Tomahawk Missile competition. This involved working closely with the Joint Cruise Missile Project Office for two months to develop an accurate and complete set of historical prices. The database is now used by several cost-analysis organizations in DoD. Mr. John Georges analyzed results of competition for Landing Craft Air Cushion Vehicles. And Mr. Lowell Blagmon and Ms. Meghan Lau analyzed results of VLS launcher and SM-2 GC&A competition, respectively. Finally, Navy contract negotiators in AIR-02 and SEA-02 were very helpful in explaining the acquisition histories of several programs, including events which may have influenced unit prices of these weapon systems prior to the start of competition.

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COMPETITION DURING DEVELOPMENT

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1. INTRODUCTION

Background

Competitive procurement of defense goods and services long has been a stated objective of the Congress and the Department of Defense (DoD). Benefits that have been attributed to competition include reduced and controlled costs, improved performance, enhanced industrial base, reduced risk, and improved quality. The potential benefits of competition have led to increased interest in the use of competition to reduce and control weapon system costs. For example, the Competition in Contracting Act (CICA) of 1984 mandated the use of effective competition throughout the weapon system acquisition cycle, except in extremely limited circumstances. The use of effective competition in this context encompasses both sealed bids and competitively negotiated procurements.

Much of the recent emphasis on increased competition has concentrated on the use of competition during production to reduce weapon system costs. Increasingly, the other hypothesized benefits of competition, improved quality and reliability, enhanced delivery, reduced risk, improved performance and controlled cost, have become objectives of weapon system competition. Attainment of these objectives may require that competition begin prior to the

production phase. This paper concentrates on the use of competition during development to attain key program goals.

Competition during development may involve competitive system validation or competitive Full Scale Development (FSD). Competition during system validation, or competitive prototyping, is a strategy in which two or more competing designs of a future weapon system are funded through a prototype stage. Source selection then is based upon the demonstrated performance of the competing prototypes with regard to technical achievements, cost, producibility, and logistic support.

Competing firms also may be maintained through FSD; however, few programs have undertaken this approach due to the high initial investment associated with funding two firms in FSD. Recent programs which involved competitive FSD include the Air Launched Cruise Missile, the Division Air Defense Gun, and the UH-60A Helicopter. Under both competitive strategies, the actual performance of the systems is a major factor in the decision of which contractor will continue with subsequent phases of the acquisition. An overview of competitive development is provided in Figure 1.

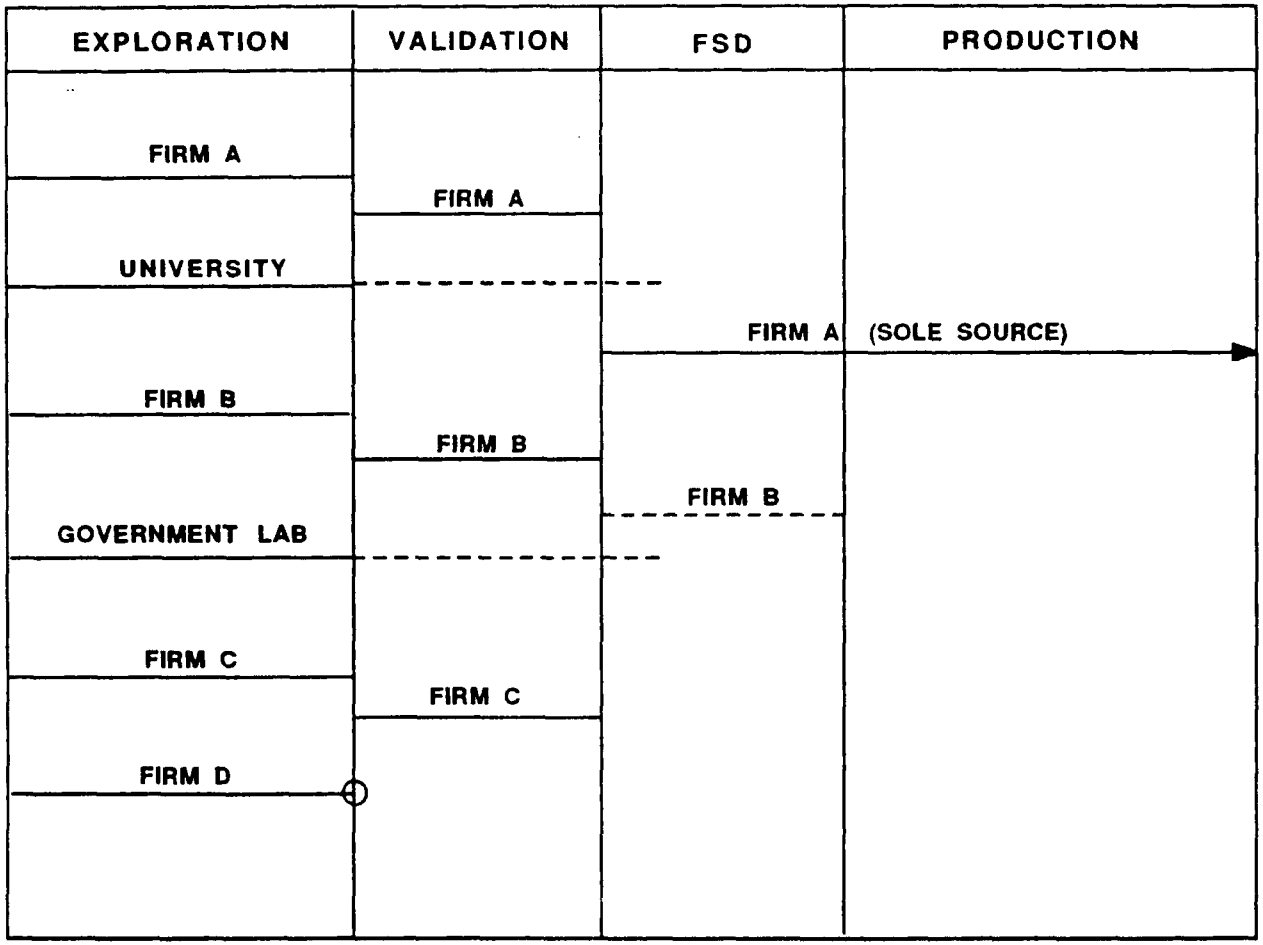
This paper discusses the use of competition during the development of a weapon system program. The results of recent programs are summarized as well as several key factors associated with successfully implementing development competition. Specifically, this paper presents a theoretical discussion of the benefits of competition during development, a summary of previous studies on this subject, the results of our recent analysis, and our thoughts on the future.

Previous Research on Production Competition

Analyses of shifts and rotations incorporate the assumption of perfect foresight and are

Figure 1

COMPETITION DURING DEVELOPMENT



used as a baseline. Relaxing this assumption results in altering the shift and rotation. Extensive sensitivity analysis is conducted based on relaxed assumptions reflecting imperfect knowledge on the part of the system developer.

2. THEORY OF DEVELOPMENT COMPETITION

The hypothetical costs and benefits attributed to the use of competition during development include both price and non-price considerations and differ between development and production.

Benefits During The Development Phase

Some recurring concerns in weapon system development are the continuing escalation of program costs over original estimates, lengthened schedules, and greater technical risk due to changing specifications. One of the often hypothesized benefits of development competition during the development phase is enhanced cost control or cost growth avoidance. The competitive nature during the development effort is expected to incentivize contractors to control cost through reduction of technical risk and maintenance of schedule requirements. It is also hypothesized that the overall technical design will meet or exceed original specifications given the competition between designs for FSD.

Benefits In Production And Beyond

The major problems found in the weapon system production and operation phases are increasing costs, poor manufacturing designs, and unacceptable field performance weapon system reliability due to an inadequate technical design. It is hypothesized that because competition during development can result in the selection of a single design for production,

developers are incentivized to provide a design suited to production with increased field performance and reliability. It has also been hypothesized that development competition reduces production costs through a reduced first unit cost (T1) going into first lot production as depicted in Figure 2.

The Costs Of Competitive Development

Development competition can affect system acquisition costs from the demonstration and validation phase through the production and the operation and support phases. Initially, costs may be higher than in a comparable single-source program, since it is necessary to fund two or more competitors' development efforts until their systems have been evaluated and a down selection point has been reached. Historically, the cost of the prototyping phase has varied from 7 to 20 percent of total acquisition costs.

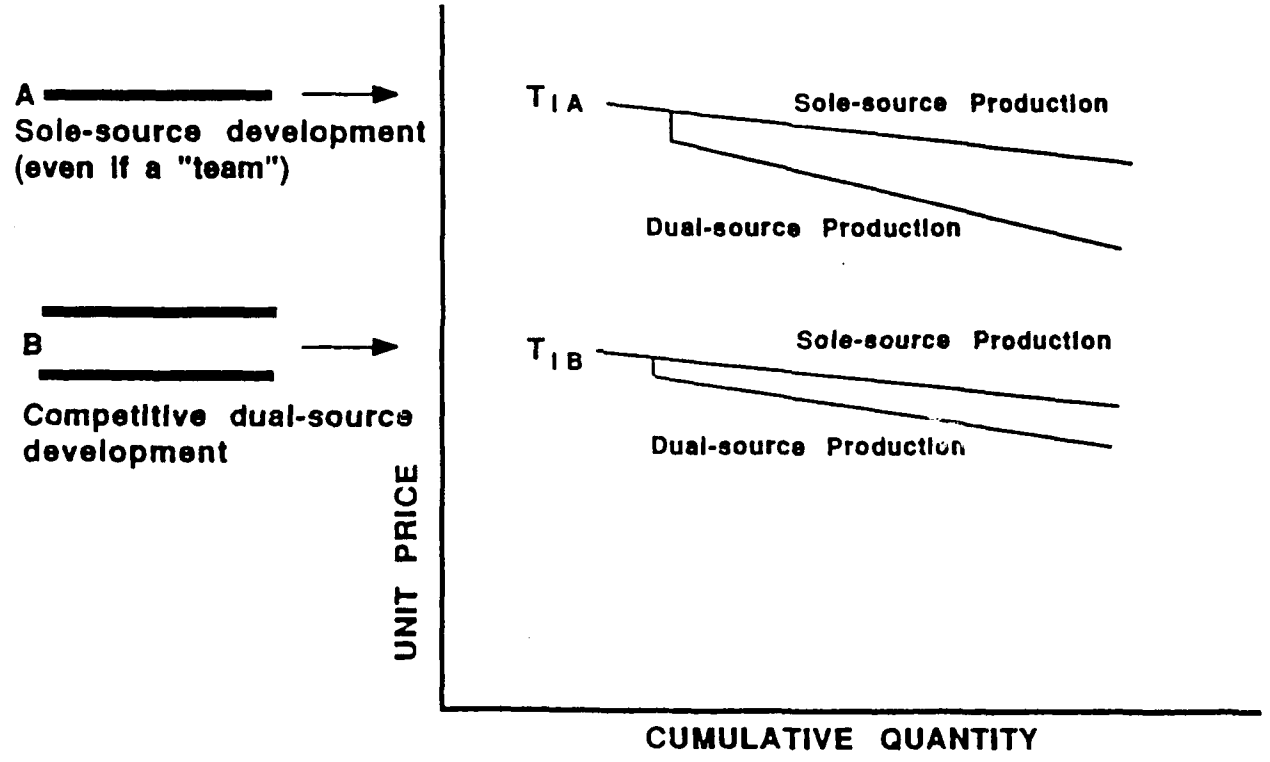
The costs of competitive development often have been mistakenly assumed to be twice the cost of a comparable single source effort. This assumption is predicated on the duplication of the entire development effort; however, it ignores the logical program restructuring that would occur to incorporate multiple contractors. For example, a single source development effort may involve the fabrication and test of ten development units. In a competitive development, the test program may require an additional five test articles for a total of 15 rather than 20. Similarly, additional government management personnel may be required to direct two development contractors; however, these personnel will not represent a duplication of the entire program office.

The most obvious costs associated with competitive development include the following:

- Redundant engineering and design efforts
- Additional test articles and test support
- Duplicative production planning

Figure 2

IMPACT OF DEVELOPMENT COMPETITION ON PRODUCTION COSTS



EFFICIENT PRICING DRIVEN FROM EARLY STAGES OF THE ACQUISITION CYCLE

- Redundant contractor management
- Additional program office management.

The extent to which these costs outweigh the benefits of development competition is often cited with little supporting documentation. Quantifying these costs is necessary in order to compare the benefits of development competition to its costs.

3. PRIOR DEVELOPMENT COMPETITION STUDIES

Few research efforts have assessed the programmatic impact of competitive development. Empirical research conducted by Rand has indicated that competitive prototype programs have experienced generally lower total program cost growth than single source programs [1]. Figure 3 presents the annual cost growth trends for SAR-level programs that involved competitive prototyping and single source development programs. The average annual growth for single source programs is 5.6 percent, while the average annual growth for the competitive prototype programs is 2.4 percent.

Cost growth for competitive development has been less in both FSD and procurement. A recent review of total program cost growth during FSD has indicated that programs with competitive FSD phases have incurred an average cost growth of two percent while comparable single source efforts have incurred cost growth of over 40 percent [2]. The percentage cost growths exclude inflation and the effects of quantity changes. The small sample size of three competitive FSD programs does not allow statistical analyses. The results do suggest that competitive FSD results in enhanced cost control.

The Institute for Defense Analysis (IDA) compiled a data set of 14 competitive (development/design) and 27 noncompetitive programs using 1982 SAR data [3]. The average annual unit procurement cost growth rate was estimated at 3.1 percent for the competitive

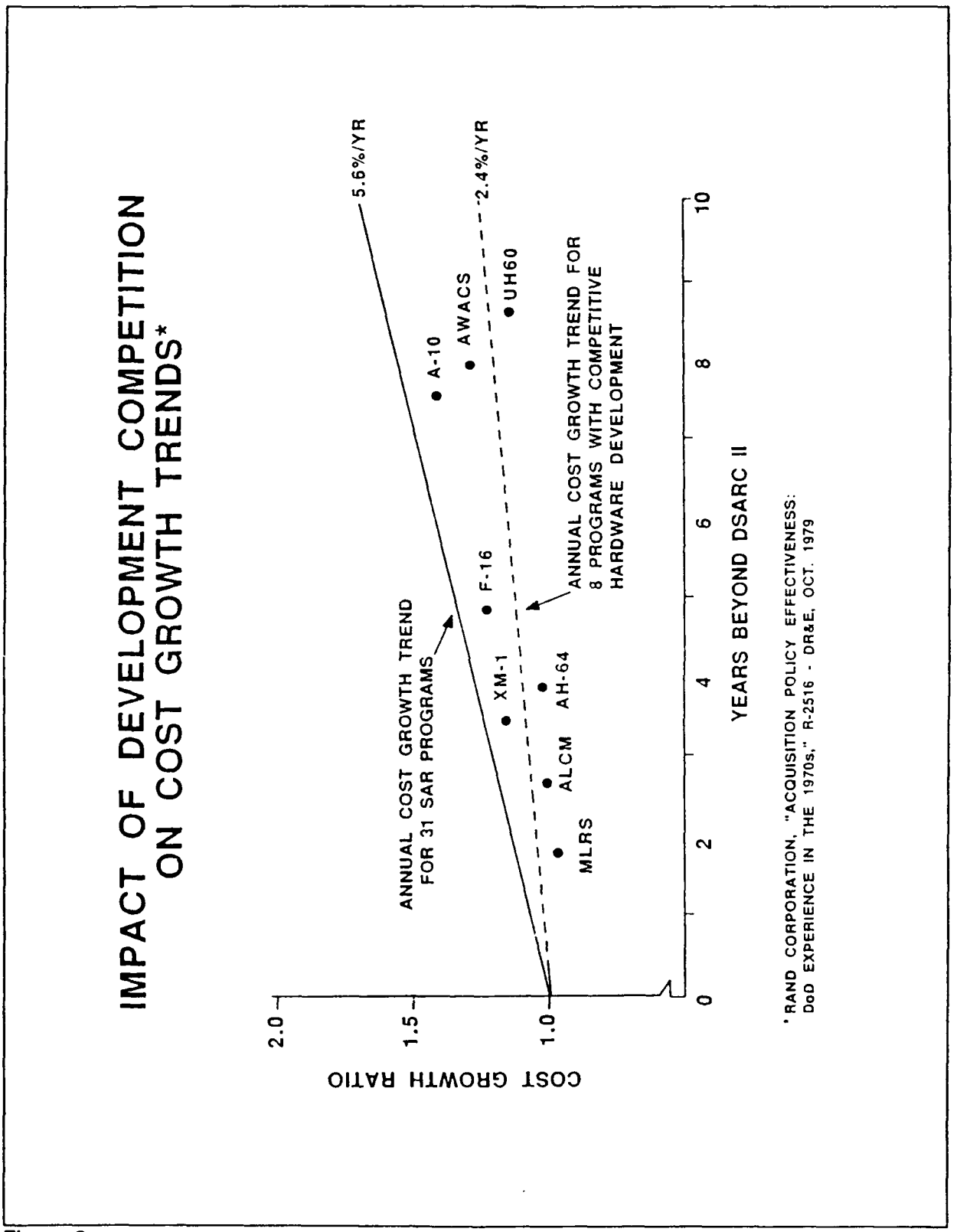

IMPACT OF DEVELOPMENT COMPETITION
ON COST GROWTH TRENDS*
5.6%/YR
2.4%/YR
A-10
AWACS
UH60
F-16
XM-1
AH-64
ALCM
MLRS
ANNUAL COST GROWTH TREND
FOR 31 SAR PROGRAMS
ANNUAL COST GROWTH TREND FOR
8 PROGRAMS WITH COMPETITIVE
HARDWARE DEVELOPMENT
COST GROWTH RATIO
2.0
1.5
1.0
0
2
4
6
8
10
YEARS BEYOND DSARC II
* RAND CORPORATION, "ACQUISITION POLICY EFFECTIVENESS:
DoD EXPERIENCE IN THE 1970s," R-2516 - DR&E, OCT. 1979

Figure 3

programs and 5.8 percent for the noncompetitive sample. The IDA paper experiments with adjustments to the data set in order to circumvent extreme sample values, as well as other problems which emerge from any data analysis. The largest problem which emerges from the analysis is the low confidence levels of the estimates arising from relatively low sample sizes and wide variability in the data. Table I summarizes the IDA report.

Table I Cases From SAR Analysis

PROGRAMS WITH R&D PROTOTYPE COMPETITION		PROGRAMS WITHOUT R&D PROTOTYPE COMPETITION			
PROGRAM	ANNUAL PERCENT CHANGE*	PROGRAM	ANNUAL PERCENT CHANGE*	PROGRAM	ANNUAL PERCENT CHANGE*
MLRS	-2.3	Sidewinder	-1.5	Stinger	6.4
DIVAD	-0.3	AV8B	-0.5	HARPOON	6.4
F/A-18	1.5	NAVSTAR	0.4	FFG-7	7.5
AN/TTC-39	1.8	Trident Missile	0.7	DSCS 3	7.7
UH-60A	2.0	SSN688	0.8	TACTAS	9.1
SLCM	2.2	CG-47	1.4	HARM	9.9
E-3A	2.8	F-15	2.6	Patriot	10.2
F-16	3.4	Trident Submarine	2.6	LAMPS Aircraft	11.8
M-1	5.7	F-14A	2.9	EF-111A	13.6
Hellfire	7.1	IR Maverick	3.3	Bradley FVS	13.6
ALCM	8.5	CH-47D	3.5	Pershing 2	22.2
AH-64	9.9	CH-53E	4.3	LAMPS Ship	22.4
GLCM	15.3	Phoenix	5.1	CAPTOR	25.8
Copperhead	66.0	Sparrow	5.8		

*Average annual percentage change in constant-dollar unit procurement cost (UPC) from time of development estimate (DE) until December 1982. Based on information in Selected Acquisition Report (U), December 1982. SECRET. Information derived for this report is unclassified.

Several hazards exist in aggregate data analysis of this type. Problems include:

- Design changes
- Quantity requirement changes

- Small sample sizes (especially for competitive programs)
- Wide variability in cost data
- Inconsistent use of design to cost (DTC) goals.

Comparison of production cost growth rates suggest that development competition may help control production cost growth. Small sample sizes, wide variability of the data, and program specific characteristics prevent a more accurate measure using this type of analysis.

The Analytic Sciences Corporation (TASC) has recently examined several aspects of some recent competitive development efforts. Building upon the previous research efforts, the TASC effort has detailed both the aggregate and programmatic impacts of competitive development. The results are discussed in the following section.

4. RECENT PROGRAMS

As use of development competition increases over time, useful insights and lessons learned should add to the knowledge base for this type of competition. Already with limited applications of development competition, significant lessons learned have accumulated. Case histories which presently yield some significant insights include SINCGARS-V, MLRS, AH-64, and ALCM.

SINCGARS

The Single Channel Ground and Airborne Radio System (SINCGARS-V) is the VHF-FM radio communications system providing the primary means of command and control for infantry, artillery, and armor units. The SINCGARS program is summarized in Figure 4.

The SINCGARS validation efforts began in April 1978, with three firms under contract to build prototypes. ITT Corporation (Aerospace/Optical Div) and Cincinnati Electronics Corporation

Figure 4

SINGLE CHANNEL GROUND AND AIRBORNE RADIO SYSTEM (SINCGARS)

- COMPETITION HISTORY
  - -- THREE CONTRACTORS DURING VALIDATION EFFORTS
  - -- TWO FIRMS PROCEEDED INTO ADVANCED DEVELOPMENT - ITT, CINN ELEC
  - -- ITT WON PRODUCTION AWARD, WITH FOUR FULLY PRICED OPTIONS

- INITIAL DTUPC GOALS ABANDONED
  - -- EARLY TECHNICAL CHANGES, ENHANCEMENTS INCREASED SYSTEM COSTS
  - -- EXPECTED UNIT COST GREW APPROXIMATELY 300%
  - -- COMPETITION FOR PRODUCTION AWARD HELPED CONTROL COST GROWTH

- RELIABILITY PROBLEMS
  - -- PRODUCTION SCHEDULE HAS SLIPPED 2 YEARS
  - -- ITT ABSORBED SIGNIFICANT OVERRUN - APPROXIMATELY $30 MILLION

were contracted to develop the slow frequency hopping (SFH) concept, while Rockwell Collins was to develop the fast frequency hopping (FFH) technique. Rockwell was dropped in January 1982 because their design offered a much higher technological risk than the other two efforts. The two remaining contractors, ITT and Cincinnati Electronics, received engineering development contracts, in parallel, with the advanced development efforts already unde , production contract award was planned for Fiscal Year 1983.

During December 1983, ITT was awarded a single year production contract with four option years. The contract was of the firm fixed price type with economic price adjustment (FFP/A). Although both contractors had technologically acceptable designs, ITT's design was further along and presented less risk for production. Production costs were the deciding factor. Before the third option was awarded, reliability problems arose during first article testing. The awarding of the final two options was suspended while ITT solved the problems. After ITT had spent considerable internal funds improving reliability, the production contract was re-baselined for award of the final two option years during Fiscal Year 1988.

During validation, when the Army was primarily concerned with technological factors, the projected unit production costs grew. The initial design to unit procurement cost (DTUPC) goals were abandoned. The configuration was upgraded and system capabilities were expanded. Once the two remaining producers proceeded into advanced development, cost became the overriding factor and projected production costs have remained under control. Also, with the presence of another contractor during advanced development, the winning firm was willing to accept a cost ceiling which, given the eventual reliability problems, resulted in substantial savings to the Army. Table II illustrates the changes in SINCGARS unit production cost.

Table II SINCGARS-V Production Cost (FY84$)

Calendar Year	Unit Cost
1978	$ 3,702 (Goal)
1982	$12,768 (Goal)
1984	$ 8,751 (Actual)

Multiple Launch Rocket System

The Multiple Launch Rocket System (MLRS) was designed to supplement cannon weapons by delivering a large volume of firepower in a short time. The MLRS, with a dual-purpose improved conventional submunition warhead, will provide an all-weather, indirect fire capability to attack the enemy's indirect fire weapons, air defense systems, and light material and personnel targets, especially during surge conditions.

The technology for the system was well established prior to program validation. Significant protions of the technology were previously applied. New development areas were kept simple. The MLRS program is summarized in Figure 5.

The acquisition strategy involved two contractors, Boeing Aerospace Co. and Vought Corporation, in a competitive validation. The winner of the competition could receive single source contracts for the $3.5 billion planned production program. The winner would proceed into a qualification phase, during which a multiyear bid for production would be submitted. If the multiyear bid held close to the projected prices which were proposed during the competitive validation, then the government planned to award the multiyear contract. If the government felt the production bid was high, then they planned to establish a second production source.

Both contractors were responsive to the program office requirements. The primary source

Figure 5

MULTIPLE LAUNCH ROCKET SYSTEM (MLRS)

- COMPETITION HISTORY:
  - -- TWO CONTRACTORS IN VALIDATION - BOEING, VOUGHT
  - -- SINGLE SOURCE FOR REMAINDER OF PROGRAM
  - -- ARMY KEPT OPTION FOR SECOND PRODUCTION SOURCE
- AGGRESSIVE CONTRACTOR PERFORMANCE DURING COMPETITION:
  - -- LARGE PRIZE - $3 1/2 BILLION PRODUCTION RUN
  - -- BOTH FIRMS ACCEPTED CONTRACT CEILINGS
  - -- VOUGHT INVESTED OVER $50 MILLION IN PLANT & EQUIPMENT
- PRODUCTION UNIT COST BELOW DTUPC:
  - -- BOTH FIRMS BID LOW (BECAUSE LOWER COST WAS "DESIGNED IN")
  - -- INDEPENDENT STUDY VALIDATED ESTIMATES
  - -- MULTI-YEAR CONTRACT - WITH THREAT OF SECOND SOURCE
- STABLE CONFIGURATION:
  - -- SIMPLE DESIGN
  - -- MUCH PREVIOUSLY PROVEN TECHNOLOGY

selection criteria were cost and performance. Both contractors reduced projected production costs by approximately 25 percent during the competition. Vought Corporation won the competition and proceeded into the qualification phase. Vought eventually was awarded a multiyear production contract as they reduced their planned production costs an additional two percent during the multiyear bid. The program office noted that both contractors were highly motivated by the large production program. Beneficial actions cited by the program office included:

- Creation of separate divisions to offload high corporate overhead
- Location of plants in low-cost labor areas
- Colocate of plants with subcontractors to reduce transportation costs
- Automation of production systems
- Agreement to substantial corporate investment
- Use of deferred methods of amortizing investments
- Negotiation of fixed price contracts with subcontractors
- Agreement to low profit percentage and FPI contracts with low price ceilings
- Acceptance of ceilings on development contracts.

Although the MLRS represents a relatively simple development effort, the acquisition program includes key features which emerge as important to a successful implementation of development competition. These features include:

- Emphasis on producibility
- Substantial reward for winning
- Cost effectiveness is primary selection criterion.

AH-64 Apache Attack Helicopter

The AH-64 carries the laser-guided Hellfire antitank missile as well as a 30mm chain gun and 2.75 inch rockets for suppressive fire. The AH-64 features a sophisticated target acquisition/designatoin sight (TADS) including a laser range finder as well as a television camera and a forward-looking infrared (FLIR) system for night vision. A pilot night vision sensor (PNVS) also is included for accomplishing several maneuvers.

Phase One was an engineering development of the air vehicle but it did not include integration of the mission subsystem. Hughes and Bell competed in this 36-month engineering development phase one effort; the winner of the competitive phase (which included a fly-off) was to proceed into a single-source FSD effort. The Apache program is summarized in Figure 6.

Cost and performance received equal weight as selection criteria. A ceiling of $1.6 million (FY72 dollars) for unit production was enforced by the program office. Proposals with unit costs exceeding the $1.6 million figure were considered nonresponsive. Unit production cost goals for the program and the contractors ranged from $1.1 to $1.4 million dollars. Hughes won the competition. Since both firms went to ceiling on costs, the selection was made on the basis of performance and producibility considerations.

During the single source (phase two) effort, several problems arose. A change in requirements led to significant integration problems. Also, with contracting now on a single source basis, most competitive pressure on costs had been removed (subsystem competitive development effort for a new TADS/PMS system was enacted, but produced questionable cost savings). After the single source Phase Two effort, unit production cost had grown to almost $4 million.

Air Launched Cruise Missile (ALCM)

The ALCM program arose from an FSD competition which was conducted by the Joint

Figure 6

APACHE (AAH-64)

- COMPETITION HISTORY
  - -- FIVE CONTRACTORS DURING VALIDATION
  - -- TWO FIRMS SELECTED FOR PROTOTYPING - HUGHES, BELL
  - -- HUGHES WON FLY-OFF, PROCEEDED INTO FSD
  - -- HUGHES - SINGLE SOURCE PRODUCTION
- COST GROWTH THROUGHOUT PROGRAM
  - --
  - -- PROTOTYPING EXPERIENCED 40% COST GROWTH FROM BOTH FIRMS
    PRODUCTION UNIT COSTS HAVE INCREASED APPROX 80%
- SIGNIFICANT TECHNICAL CHANGES IN FSD
  - --
  - -- SWITCHED FROM TOW TO HELLFIRE MISSILES
    REQUIRED DEVELOPMENT OF TADS/PNVS - DUAL SOURCED

Cruise Missiles Project Office. The competition matched the Boeing ALCM versus the General Dynamics Ship Launched Cruise Missile (SLCM), with Boeing eventually winning the production award. The objectives of the competition included cost and schedule control. The competition featured a pilot production and fully integrated launch from the B-52.

A major objective of the ALCM competition was to control unit production costs. Firm bids on pre-priced production lots were required. Several cost reducing design changes resulted from the competition. The competition was introduced after the two competing designs were relatively firm, allowing the competitors to concentrate on reducing unit production costs.

When the ALCM went into production, Boeing attained the first unit goal of 5669 labor hours. The program office projected a labor hour cost improvement rate of 0.85; however, Boeing realized a 0.65 cost improvement rate for the initial production lots, as depicted in Figure 7. This significant reduction was attributed to Boeing's "Curvebuster Program" in which cost-reducing measures were implemented throughout the facility to enhance Boeing's ability to attain their competitive production bid. As a result, the average unit cost of the initial lots was 20 to 30 percent less than originally estimated.

Summary

Examination of the case studies revealed specific examples of procurement cost savings attributable to development competition. These examples include:

- Major design innovations reduced cost and improved performance
- Costly design features were avoided without degrading system capabilities
- Cost/performance tradeoffs eliminated certain capabilities that the contractors found (with government encouragement) to be too costly in light of service priorities and design-to-cost (DTC) goals

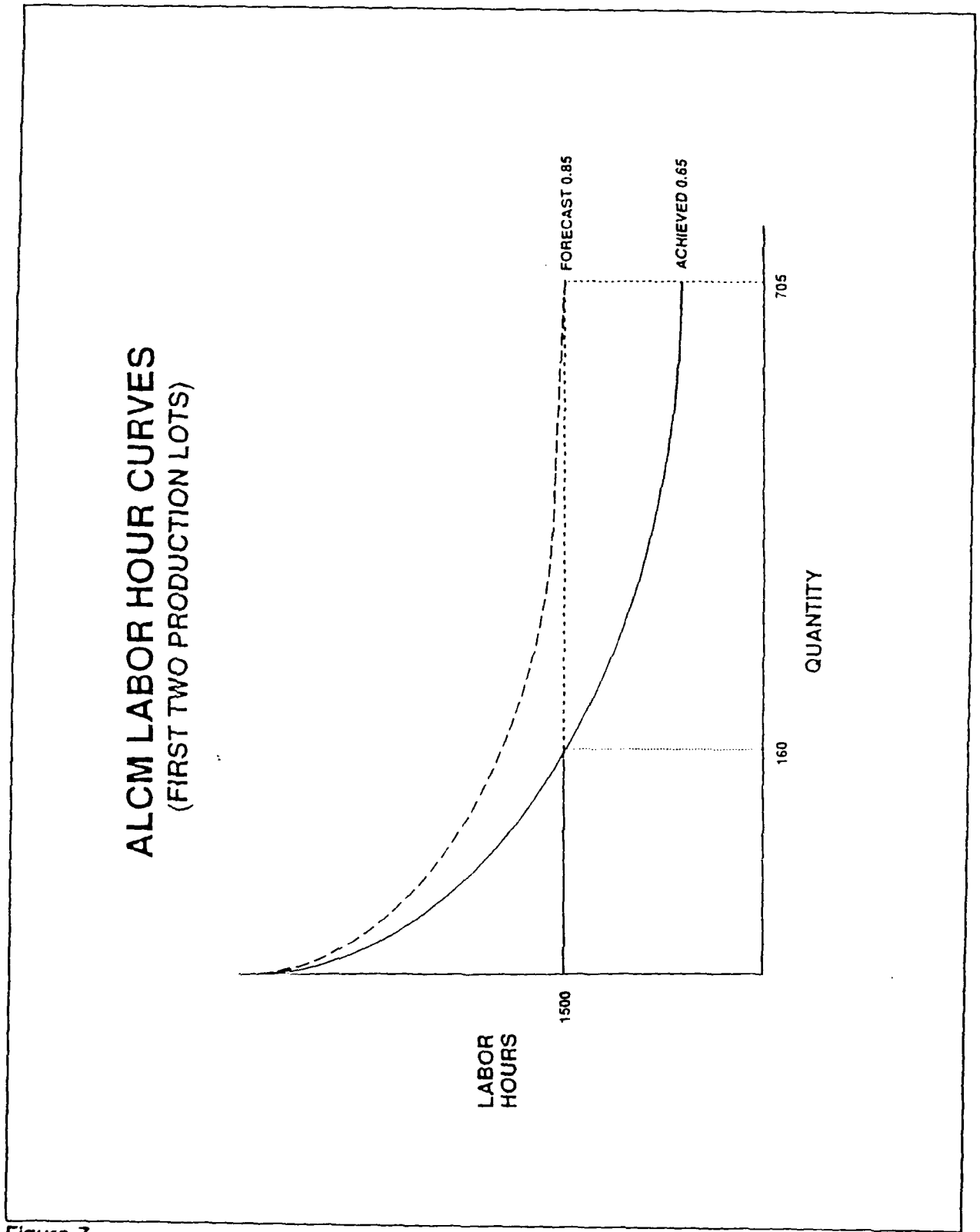

ALCM LABOR HOUR CURVES
(FIRST TWO PRODUCTION LOTS)
FORECAST 0.85
ACHIEVED 0.65
1500
160
705
LABOR HOURS
QUANTITY

Figure 7

- Producibility changes to designs and production methods had important cost-reducing impacts.

5. CONCLUSIONS

With the defense environment entering a period of budget austerity, policymakers must focus on the benefits of dual-source competitive development efforts. Evidence indicates that the initial costs and risks of a dual source development effort are often rewarded by a successful long-term program. If the program manager's objectives (e.g., production cost ceilings, performance requirements, life-cycle cost goals, schedule constraints) are achieved, then the initial risk of a competitive development was worth the upfront investment.

A comprehensive cost-benefit approach is clearly required. The initial costs, risks, and administrative requirements of conducting a dual source development must be evaluated against the future rewards of a successful competitive effort. These future rewards are not only defined on a programmatic basis, but are determined by program management when the competition is structured. Potential rewards which may be evaluated during a cost-benefit analysis include:

- Production cost savings
- Schedule maintenance
- Support cost savings
- Performance and quality improvements
- Industrial base considerations.

Research at TASC has concentrated on building an effective cost-benefit methodology. The initial effort consisted of both a compilation and an examination of a comprehensive data base. The collection of data is ongoing. Currently, relationships are being identified, quantified, and coded into a cost-benefit model. This effort will ultimately provide program managers with

a methodology that will help determine the likelihood of success for alternative development competition strategies.

Difficult and challenging decisions lie ahead if the services are to increase the use of development competition. Policymakers must recognize the significant future rewards in order to allow the necessary upfront funding. The services must accurately define long-term objectives when deciding on whether to use development competition. Program management must structure the competition in a manner that drives the contractors to the desired goals. As the frequency and use of development competition increases, important lessons learned must help provide a path for future programs in this area.

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COMPETITION IN WEAPON SYSTEM ACQUISITION:

A ROUNDTABLE DISCUSSION

Discussants

RADM William C. Carlson, USN
Assistant Deputy Commander, Naval Sea Systems Command

Dr. John J. Hamre
Staff, Senate Armed Services Committee

Dr. David L. McNicol
Deputy Assistant Secretary of Defense

Moderator

Dr. Daniel A. Nussbaum
Naval Center for Cost Analysis

A roundtable discussion was held on 8 September 1989 on the final morning of the Symposium. The Symposium was very fortunate to have these three distinguished panel members available to discuss various aspects of competition in weapon systems acquisition. Their vitas follow the transcript.

Questions for the discussion were proposed by the moderator and were modified with feedback from the discussants into final form prior to the discussion. The following is a transcript of the entire 75 minute discussion, although redundant portions have been edited.

NUSSBAUM: Do you think that most people's opinions about competition are grounded in data and analysis, or are they opinions and prejudices, and I'll ask Adm. Carlson to address that question:

CARLSON: Well, I think the way the question is phrased tells pretty much what the answer really is. It says, "Are most people's opinions about competition, etc." What we have are opinions, because very seldomly do we procure any given device both ways. If you really wanted to know the ideal answer, you would have to procure it both ways. This would give us a control, and then we would compare the control group against the competitive procurement. We cannot do that, not in this business. Therefore, we are reduced to the fact that we have to perform predictive analysis in order to make the decision. Then we go back afterward and either claim victory or have to acknowledge defeat. I think that is where you as cost analysts come in, because you will be the personnel that have to change the fear and superstition that is the current basis for our decision on competition and put the decision on a firm analytical basis. Claims of 25% savings due to competition by comparing the contract price to the budget are of somewhat questionable validity. As we gather additional data, you cost analysts will be very deeply involved in going over the data, validating the assumptions that were made initially, and providing a predictive tool which can be more effective. We hope that competition will bring fairer prices and be effective in defense acquisition.

HAMRE: I have to start with an announcement which is I'm allowed only to put at risk my own career, so therefore my comments are mine alone and don't reflect Senator Nunn, for whom I work, or the committee. Please honor my request that these comments are strictly my views. First, on a broader and more philosophic starting

point, I'd like to echo some of what RADM Carlson said. Competition is one of those icons in American politics, like the flag, the pledge of allegiance, and free enterprise. Everybody loves these things, and they are cited in everybody's speeches. However, I spend much of my time fighting people who are trying to limit competition. You know, business really doesn't like to compete. They love monopoly. So we tend to have a dichotomy in our society between public rhetoric about competition and the reality. And, of course, that comes to a focus in an organization like the Congress which is inherently a political organization, and I don't mean partisan when I say political and I don't mean politics. What I mean is that Congress is an institution which must resolve questions that can't be resolved anyplace else. These issues can't be resolved in a court of law; they can't be resolved in the marketplace; they can't be resolved administratively. You have to solve them politically and come up with a compromise where you reconcile competing goals against a finite amount of resources. Those are inherently politi- a' decisions, and that's not a bad thing. You have to have a mechanism in our society to do that. So you find this tension between the rhetoric about competition and the reality which comes to a very crisp focus in Congress all the time. Now to the precise wording of your question on the perception of competition: is it based on facts or is it based on prejudice? RADM Carlson said that so much of the whole business with competition, especially the claims of savings, is determined before the facts are in. That is a problem that we live with in Congress all the time. Everything is inherently prospective. When we decide whether or not to authorize and appropriate funds for M1 tanks in fiscal year 1990, we're making that decision in fiscal year 1989, we won't start building them until

1992, and you won't see the final cost accounting until 1994. So everything is inherently prospective and by definition that also means it is inherently political. That means, of course, you can't document anything that hasn't occurred, and so competition tends to enter into Congressional debate as part of the currency of the debate. Now, that's not atypical of debate on the Hill. There is no set of data upon which people are acting, save for what you cost analysts produce. So I would echo very much what RADM Carlson said, that the starting point of rational choice, when it comes to the issue of competition, has to be with the best analysis that we can bring to bear in advance. It will help. It won't necessarily make the outcome the best outcome, but it will help to avoid the worst outcome.

MCNICOL: I get my licks in on this issue very frequently, so I will be brief, but not silent. I agree with the thrust of RADM Carlson's comments that, while the positions taken on dual sourcing are based on data and analysis, the data and analysis that we have available are really inadequate. Let me offer two little pieces of evidence in favor of that. First, I have never heard anyone, in the context of the CAIG or anywhere else, offer an argument demonstrating that dual sourcing will, in fact, produce price competition. It is always simply assumed that dual sourcing will produce price competition. That cannot simply be assumed, because it is perfectly possible to structure an acquisition strategy so that you have, in effect, two single sources. Moreover, those two firms may bid price up rather than bid price down to cost. Second, I think there's a logical problem that we often shy away from when using historical data. You can imagine using an average to predict the next element of the sequence 3, 6, and 9. The average is 6, which involves 50% error if the next element is 12. Even in the world of cost analysis for

budgeting that's a big error. But, without any apology, we often take a sample of systems that were dual sourced, then we average the data and say that the result will be characteristic of the system in question. I think we would do better to consider the issue of what are the similarities and what are the differences between the system we're talking about and those in the database. As we go on in the conversation this morning, I will suggest that such a look will point to many relevant differences, and to say that a particular system is dual sourced instead of sole sourced does not say very much.

HAMRE: Well, I'd like to say more concerning this issue of facts versus perception. There is an alarming quality where facts are made adjustable when the political requirements demand that we support one course or another. Let me use as an example the Phoenix Missile. I remember when a senior member of the Defense Secretariat came over to talk to me about the analysis which showed that it was cost effective to qualify a second producer for the Phoenix. A second source was cost-effective only with inflated inventory goals. The inventory objective was jacked up to 7,000 missiles, when only 4,500 were required. Then we spent $95 million to qualify a second source producer, and now we are having the first year of competition. Yet the pending budget proposes to terminate the Phoenix dual sourcing program, and the inventory objective has dropped back to 4,500. The best analysis that any of you folks could bring to bear wouldn't make a whit of difference in that kind of an outcome. That was politics. And in the same way, we have this situation for almost every missile program this year. We've got competition on the Standard missile, on HARM, on HELLFIRE, starting on Stinger, and on TOW. On every one of these programs, right now, we are procuring these

missiles below the minimum efficient rate for one producer. And yet we spend all this money qualifying a second source producer. So if we're going to have competition, and I think that missiles are among the most productive areas to have competition because the units to be procured are large enough and efficiencies are great enough to justify competition, you have to buy what you say you're going to buy. And we're not doing that. So, in recent years all the benefits of competition that we sought in missiles are like purchasing a bond and deciding to throw away the coupon. If we're really going to make a decision and embrace competition as acquisition strategy, we've got to carry through. If we don't carry through, we've wasted the taxpayer's money.

CARLSON: I think that's one of the very fundamental things that I would like to emphasize. I agree with Dr. Hamre but only partially. Because of the emphasis we've had on second sourcing over the last few years, we have lured companies into making significant investments on the promise of a chance to recoup that investment and make a profit in the future. That has given our acquisition plans and strategies a great deal of inertia. How many times will General Electric or Westinghouse make a $100 million investment on the promise of some business in the future. Once, perhaps. But trick me twice, shame on me. I recall a conversation that I had with Norm Augustine on this very issue when we kept getting into more and more competition. He made the comment that it was becoming impossible to make a buck, and he was thinking of getting out of the defense business. I said, "What are you guys doing? Why doesn't industry just say no? That's enough. We're not going to make any investments." He has a way with words, as you know. He looked at me, and he said, "Bill, when someone comes at you with a gun in his

hand and asks for money, your first inclination isn't that he's trying to sell you the gun." And to a large extent that's the way industry approached this issue. We forced them. We have an interesting economic situation. We have a relatively large number of suppliers and only one customer. We have established the conditions of the defense business. And now we have said that these conditions are no longer favorable, and we're going to change them. It was not very long ago that General Electric was suspended because they refused to give their proprietary data on jet engines to Pratt and Whitney so that Pratt and Whitney could compete. And I'm sure you noticed that approximately two weeks ago an announcement was made that the contract for the jet engines was let on a winner-take-all basis. General Electric won a contract year and, I believe, four option years. If you are a Pratt and Whitney type individual you might view this slightly askance, in that, if you didn't have a contractual arrangement, you certainly had an implied promise that we would maintain our previous conditions. Unfortunately, we in the Department of Defense are in no position to ever make this type of guarantee to any company, or even to imply such a guarantee, because our masters in Congress are the ones who decide what we can and cannot do. It's a quandary.

MCNICOL: Let me pick up on an aspect of this; one of PA&E's perennial arguments is that if a system is dual sourced, the planned annual buy must be large enough to justify dual sourcing, and the buy must be executed approximately as planned. Departures from that ideal cannot be put entirely on the Defense Department's back, I should note. I would also like to comment on the question of investment by individual producers. They certainly don't like the idea of making an investment

which is not recouped and which, in fact, is not guaranteed. As I understand it, that is no longer really a prospect, due to legislation now on the books that, in effect, guarantees that firms which do make a capital investment under dual source circumstances will get it back. It's not at all clear to me that this is a wise course. If you're talking about competition--in the sense that competition is used in the private market--it means that you have your company's money on the line and you will not necessarily get it back. In fact, the goad of not necessarily getting your company's money back is a large part of competition, and one of the real enforcement mechanisms in competition is the failure of firms which results when they do not make the correct economic choices. It is not at all clear to me that the folks who have favored competition have really understood what it is that they're favoring. But if what we really want is competition, we must be prepared to do things like see companies losing money on defense contracts.

NUSSBAUM: Is there some prospective way to tell what systems are particularly attractive or particularly unattractive for dual sourcing and competition? Or is it all a dice throw?

CARLSON: I'd be happy to take that because I'm one of the guys who has to make those types of decisions and start the programs off. There are certainly a large number of people interested in my decision as I go through the large number of decision-makers and ankle-biters that influence my position. The ankle-biters are always interesting because they are in a position to say no or to torque your program, but they don't accept any responsibility for the success or failure of your program. It's just that they have a special interest that allows them to torque it.

HAMRE: Please let me offer a general comment, and please interrupt me when you desire.

This is a philosophical perspective on competition. Competition is probably the right way to proceed when the budget is expanding. It's probably the wrong way to go when the budget is contracting. It's my personal view that there has been a competition between two strategies--dual sourcing and multiyear procurement--with the Navy being the primary advocate of dual sourcing and with the Army being the primary advocate of multiyear contracts. I think that the overall environment suggests that you're probably going to do better when the budget is expanding by competing systems, as a general philosophy. But when the budget tightens up, you're probably going to do better, in price and quality, by pursuing a multi-year strategy. I think that's a general perception on the Hill.

CARLSON: I think that's absolutely true. I think also, though, you have to look at what you're talking about in the way of equipment. Dr. Hamre previously used the example of missiles. You have to procure a large quantity of any system in order to make it economically realistic for more than one manufacturer to operate a continuous production line. Obviously there must be economies associated with that. As was mentioned earlier in the discussion, if you're procuring less than an economic order quantity in the first place, it is difficult to divide production into two pieces and have either of those be of economic order quantity. That's pretty basic. So you have to have something that you will procure in quantity. I would also prefer, when we start talking about dual-sourcing, to have something that has multiplicious application. For example, transistors, IC's, basic components, or standard electronic modules can be used in many things. Why do I say that? Because you must assure a manufacturer, who is going to make an investment, that there is at least a reasonable market in the future. If you're dual sourcing one program with

only one application, because of the way that our system works in annual budgeting, there is inherent risk. So I would think that the most attractive items would be multiplicious in application. When you get to very large items, I think it's a big mistake to ask for a second source in something that requires a phenomenal investment on the part of the company. I'm talking in terms of hundreds of millions of dollars. Take, for example, the SQQ-89 that some of you are familiar with. If, in fact, you're buying perhaps only thirteen combat systems a year and you divide that between two groups, it's hard to see how a producer is ever going to recoup his investment. We said, "You fund your own start-up costs, you get qualified, you get started, and then we will give you a chance to compete." Even on the government side, there are serious ramifications to this approach. Take, for example, special test equipment. By law we will pay the contractor for his investments on a five year amortized basis for any special test equipment. Well that's really great, but if I change contractors six years from now that means that I get to buy the equipment again even though I already paid for it once. I not only paid for the equipment, I paid for the cost of money associated with it, but now I still don't own it. So now I have to buy it again if I'm going to change manufacturers. Well, this puts me in a position that I don't want to be in. The whole reason we wanted to use competition in the first place was that we didn't want to be over a barrel, with the contractor's hand in our pocket, when he is the sole source and I can't get anybody else to produce the system. We should qualify a second source for a whole host of benefits: competition, broadening of the industrial base, mobilization enhancement, etc. But the system should be something that we buy in large quantities, it should have multiplicious application,

and we should be able to anticipate that it's going to be required for a long period of time. You know, buggy whips are not in great demand today. You don't want something that's going to be eclipsed by technology very quickly.

MCNICOL: Let me generalize the points you made concerning the sorts of systems that will be prime candidates for dual sourcing. It seems to me that there are three criteria that you might look to fairly specifically. One is low facilitization costs; second is not much change in unit cost with quantity; and third is not much loss of learning with changes in quantity. Those three conditions are satisfied, as you say, by the systems that DoD buys in very large quantities; missiles, for example. Interestingly enough, they can also be satisfied by some systems DoD buys in very small quantities--ships. A very interesting question it seems to me that hasn't gotten the kind of analysis that it deserves is, "Just how is it that those two cases are similar and different?" What kind of case can we really make a priori for dual-sourcing ships? The problem there, as you're well aware, RADM Carlson, is that you have to start, at some point, thinking about the complexity of the systems you buy and whether that complexity in and of itself is going to defeat dual-sourcing. There's another broader point that Dr. Hamre brought up, on which I can offer some further comment. Viewing this deliberately as something of a technician, it's not obvious to me why dual-sourcing would be more or less attractive depending upon the direction the budget's going. My assumption is that Dr. Hamre is speaking not so much to stable economic facts, but to what is likely to happen to the programs as they go through the budget mill in the Department and then in the Congress.

HAMRE: Yes, this is not a case as a analyst where the government gets its best return in

value from one technique or the other, but those past several years of unusual growth in the defense budget has dramatically overinflated our expectations, and a lot of people embedded the assumptions of continued budget growth in their planning and pricing. And the government, frankly, justified a lot of those competitions based on the assumption of unrealistic budget growth. I think we're going to be startled by how very little we got out of dual-sourcing.

MCNICOL: Were you referring specifically to dual-sourcing or that we mispriced those early systems?

HAMRE: When someone tells you, "I don't care what you think the requirement is, the quantity is now 7,000; now do the numbers." It's that sort of thing that I'm talking about. The problem that we had during the mid-80's, and this is not a partisan comment because curiously we had the reverse problem during the Carter Administration, where we dramatically overstated the amount of money in real terms that was going to be available in the out years of the FYDP. So it was possible to shove so much more program into a five year plan than we could ever realize. When we actually got to that out year, it could be accomodated only by introducing inefficiencies in the way we bought everything. We had exactly the same problems in the Carter years by underestimating inflation. So when we actually got to the out years, there was dramatically less real growth than was anticipated. I don't know that there is, from a technical standpoint, any way that you can solve these kinds of macro problems that are cultural in nature which are embedded in a political process. I'm not suggesting that such a broad strategy be uniformly applied; everything has to be done on a case-by-case basis. I think philosophically from our perception, given this trend that we're entering a period

of substantial uncertainty, i.e., static and declining budgets, it probably isn't the best time to bet on savings from competition. It's probably best to preserve the savings you can and maximize quality within multi-year contracts, as a general proposition.

NUSSBAUM: Perhaps we can switch to an acquisition question. Right now we have many contractors that are teaming during the R&D phase, and later they will be split apart during the production phase. Is this, in your opinion, a reasonable acquisition strategy or are there better strategies?

CARLSON: Let me take that, because I do have an opinion. I have opinions on most of these issues. I've been in acquisition management since 1982, and for a sailor that's a long-time in scenic Washington. But on this dual-sourcing issue, we have created some very strange bedfellows. Under the aegis of competition, we've taken people that have traditionally been competitors and we have put them together. We have taken people that used to be together and we've rent them asunder. Let me give you an encapsulated view of something that has happened. I have become more involved with industrial associations and nonprofit organizations--American Defense Preparedness Association, National Industrial Security Association, and groups of this type. If you go back before we had competition, we had what I call the baronies in production of Navy systems. That was a time when, if you were talking about surface ship ASW, you were talking about General Electric in Syracuse, New York. If you were talking about combat systems in submarines, you were talking about IBM, Manassas. If you were talking about torpedo producers, you were talking about Clevite in Cleveland and Honeywell in Minneapolis, in heavyweight and lightweight, respectively. These were baronies.

As a result, a very interesting thing happened. Because of the clearly established supremacy of one firm in an area, we were able to maintain top-notch quality groups of engineers over long periods of time at a given location. Let's use General Electric at Syracuse as an example. Since they started in the late 1950's, they have been a primary producer of surface ship ASW combat systems. They had a series of programs, and as one program of RDT&E geared down, another one would start. They were able to maintain a demand for quality engineers, not just production engineers, but R&D engineers, over a period of 30 years, because they kept having programs that followed, more or less, heel to toe. Prior to competition, the government and GE came up with a tremendously effective and useful algorithm for automatic detection and classification of acoustic signatures. We tested it in 1982 and it really worked. We got the IBM people and the Raytheon people, and we ran them all up to GE to brief them on this new algorithm, which was developed by GE, so we could have it applied in submarine combat systems and in torpedoes, because it was very important. Those things, ladies and gentleman, do not happen today. Today, every one of our prime manufacturers is sitting there hiding what he's doing. You go to an NSIA or ADPA meeting and, unlike before, no one stands up and tells what marvelous new thing that they have developed in their company which could be applicable elsewhere, because of the fear of competition and the fact that your partner in this procurement is your competitor in the next procurement. We are compartmentizing very much to the point where there is no information flow. Most of these meetings now have gotten to the point where industry doesn't even send engineers anymore; they send the marketeers to these meetings. It used to be

engineers exchanging technical information to the benefit of all the companies involved and to the benefit of the government. So is this a down side? Yes, I think it is. I think it's a clear down side. I think there was certainly an up side to not having this mix-and-match that we currently have. You can find that in every one of your major contracts today, where, for example, you'll see Raytheon lined up next to GE and IBM, and on the next contract they're competitors. That does not enhance communication or cooperation between the groups. There's another thing that happens when you get this teaming effort, especially when you are a potential competitor. You have no vested interest in the prime being successful, if you are a small piece of the contract. As a minor team member you are, perhaps, on a fixed price contract, you're doing one box or two boxes; you're doing a series of algorithms and now the prime is going to integrate it and make it into a system that he's selling. He's making more money than you are, but you're going to compete with him for that same system two years from now. Are you really interested in his success? I submit that you are not. That situation is to the detriment of the government, because our contractors have to be interested in successful applications of their products and they are not in this mix and match situation. And, no, I don't have a solution.

MCNICOL: Let me try to put a cost analysis spin on the question, if I can. I think it's a critical question and it's one that I've not heard addressed in the cost community. You can envision the two polar cases. One is where you dual-source late. That's a situation where an item has already gone into production, or nearly into production, and you bring on a change in the acquisition strategy, a second source. That is in contrast to a case where you deliberately begin dual-sourcing,

perhaps as early as milestone one, as part of the acquisition strategy. Now if you take that late dual sourcing case, the obvious question, I think, for a cost analyst to ask, is why would dual-sourcing save you any money? Is the answer that the savings will come out of fee? Or will the savings come out of firing engineers? The latter may save you some money, but it's also likely to reduce the quality of the product DoD gets. Or do "savings" come from shifting engineers from one contract to another, with no net savings to the government at all. Those questions might lead you to say, "Aha, if I'm really going to do dual-sourcing and get some benefits out of it, I ought to do it early, because that's the point where the real decisions are made on the design of the item and on manufacturing, and there is flexibility there to get cost savings that are more substantial than moving engineers from one contract to another." That's on the one hand. On the other hand, it's a little hard for me to tell a story about two firms who are going to cooperate closely for six or eight years in full scale development and then, when somebody blows the whistle, all of a sudden become fierce competitors. Yet, that's essentially what we're asked to believe about how early dual sourcing works. I don't have a resolution to these sets of questions. My point is that these are real questions that the cost community ought to address. We ought to have positions based on analysis and data as to the different effects on costs that we can anticipate from early and late dual-sourcing.

HAMRE: I don't have anything to offer that would help. However, I think that really gets back to what RADM Carlson said about the old baronies. You know, in many ways, we now call that kind of behavior total quality management. The Japanese, from whom we're learning how to build cars, don't focus on price. They focus on

quality and reliability. That really was the touchstone of the way we ran the defense business in the 1960's and 1970's. It's really in the 1980's when we have embraced these very aggressive procedures. It has become a political ethic to force competition, the Compeition In Contracting Act, etc. This very much cuts against the grain, in my view, of the new trend toward total quality management, of managing to procure quality and value, and not necessarily obtaining the lowest price. We are preoccupied in Congress with price, and I think we have to change our cultural thinking on the Hill about that. It's not just trying to find the lowest price right now, but the best value over time.

NUSSBAUM: Actually that leads into the question of whether economic goals are the most important goals in dual sourcing and competition. Is it the money and profit, the economic goals, that are at stake, or are there other goals at stake from our perspective and from the perspective of the producers?

HAMRE: Let me make just a very brief comment from the very superficial level that I have when looking at it from the Hill. While price is almost always the selling point for competition, I believe the greatest benefits almost invariably appear elsewhere. Seeking a second source producer of Phoenix missiles was pursued primarily to free the Navy from depending exclusively on Hughes, for example. That's really what was behind the Phoenix competition, and I think there's something important to be said about that. While we've departed from the notion of baronies providing quality over time, industry has changed during this period as well. Finance and accounting guys have taken control of corporations, and they're looking for short-term profits. The change that's going on in the industry has forced them to be a little bit more aggressive and less generous in sharing this technology and

expertise to the best value of the government. In other words, we get gouged a lot of times by companies when they've got a monopoly, so we enter into uneconomical competitions to get away from that. I really think we need a more mature relationship between business and government. I think we all have to step back from our six-month profit maximization syndrome, or political maximization syndrome on the Hill, to a view that it's a much longer term relationship. I think that's a more important kind of cultural change. Again, how we'll do that, I don't know. We certainly should start on the Hill.

CARLSON: Let me give you an example of the dichotomy we have here. I wasn't making an argument for or against competition before; I was telling you some of the down side of it. There are definitely up sides. Some of the things we get out of competition and dual-sourcing that we wouldn't have otherwise are the benefits of competition; whether it's price or not, we could argue that. This is especially true when you get to the point where there's no swing quantity; you get down to the bare survival level for two companies, and you promise them that you're going to keep them both alive. Dr. McNicol brought that up before. However, you can end up in a bidding war where two guys are arguing over who's going to get the highest price, because they want to make the most money on the least quantity. You've got to protect against that, and there are schemes for protecting against that. But you do have competition. You do have additional qualified vendors. Now an additional qualified vendor could be very important, especially in the case of labor unrest or in case of a natural disaster. We've had explosives plants that have blown up in the last two years. If you have only one source and then all of a sudden it's dust, you have a problem. Competition does enhance the

mobilization base. Now mobilization is something that we don't think about very often. We talk about the next war will be a come-as-you-are war, etc., and we shouldn't worry about mobilization. Well, that's a very long walk on a short pier, because if you're wrong and you have no mobilization base, it will be a short war, I guarantee you. You may not be on the winning side, though.

MCNICOL: Let me return to the early versus late dual-sourcing question. It seems to be a very wide consensus that dual-sourcing is definitely something program managers would like to have in their pocket, and that ought to be in our arsenal to use. From that point of view, dual-sourcing does not present any deep questions. We would want to use it when we have troubles of one sort or another, and the issue would be, "Is the price that we're paying worth the trouble that we're curing?" It seems to me that the much harder question is dual-sourcing early as a deliberate acquisition strategy, one used when DoD is trying to get a break on price and other considerations really don't play. If that's what we're interested in, we've got to stand up to the question of "Are we willing to do what's necessary to get competition?" I think Dr. Hamre quite rightly points out that this then leads to the question, "Are we willing to lock ourselves into an acquisition strategy over time that really brings those benefits to pass?" Is that a lead-in to the last question, "What's the future of second-sourcing?"

NUSSBAUM: Yes! What's the future of second sourcing in DoD? With projected cuts in quantity, are we returning to an era of sole-source procurement?

CARLSON: Well, let me make a comment on that. There has been this veiled idea of uncertainty that we keep bringing up. We need to know the future of second sourcing in advance because strategies have inertia. This uncertainty all points to

my left and to Dr. McNicol's right, to the representative of the Congress. We in DoD are not our own masters. When the Executive Branch comes forward with a strategy, whereby we have determined that there are some things that we can live without perhaps, we find that one branch of the legislative portion of the government has determined that some other things are more important. Not, I'd like to point out, the branch that Dr. Hamre is representing here! But we are not our own masters and we do have to obey the will of Congress.

HAMRE: Gee, what an introduction! I'm not going to make excuses for Congress as an institution. I think we in Congress are absolutely preoccupied with an awful lot of trivia. Who cares if we buy 15 or 16 of some system in one year? You wouldn't believe how we fight over these trivial issues. We go through all kinds of machinations to decide whether we'll have round or square chaff dispensers on aircraft. The primary reason that this happens, of course, is because contractors come to their representatives and get them to be their front men for a battle in Congress that they lost in the Pentagon. So Congress does a lot of violence to the defense budget. But not to make excuses for the Congress, a lot of Congressional micromanagement occurs because decisions didn't get finally and fairly resolved within DoD, as they should have. My personal view is that Congress will invariably improve a good budget submission and it will always worsen a bad one. That's a basic problem, and I'll get fired if anybody in this room quotes me, so I'm counting on your generosity! We're just not an institution that's going to improve faulty products that come over, because all of the people that were battling it out inside the Pentagon and didn't resolve the dispute will simply get people on the Hill to continue their side in this pitched battle. It really does help

if we get a good product to begin with. That's the first comment. The second comment is that there has been great uncertainty within the Department of Defense over the last five years. The uncertainties stem from the Department forecasting unrealistically high growth patterns in the Services' budget and Congress refusing to guarantee stable funding patterns longer than one year. Both Congress and the Administration are culprits in this. In the Weinberger era we would get these budgets projecting incredible growth rates in the outyears. For fiscal year '90, the original Weinberger FYDP was over $475 billion, and we're going to be at $300 billion. You don't have forecasts like that, with all the detailed planning that goes into them, and then have to cut them back without having enormous inefficiencies. Congress is equally to blame because it would adopt a budget resolution one year and then rebase it in following years at a lower level. And, so, it's this dialectic between the two bodies that has been the primary contributor to this terrible instability in the acquisition process. I share your frustration that Congress has tended to legislate some minor items, such as breaking out spare parts, etc., and nobody's focusing on the major acquisition issues. As an institution, we do tend to shoot the wounded. Hence, I'm willing to accept your criticism of Congress in this regard. But all of that is preamble to what I did want to say, which is by and large, Congress has agreed to your acquisition strategies. We agreed to the Phoenix dual-sourcing, and we're going to agree to its termination. We agreed to multi-year contracts on the LHD's, and we agreed to the competition on every one of the missile programs. We basically accept your acquisition strategy, whatever it is. But all of us have to have the maturity to realize that ultimately we all work for the same client, the same sponsor, and that's the taxpayer. It's not a tug of war

where DoD is on one side of the rope, and Congress is on the other. We are all--both DoD and Congress--on the same side of the rope, and we're trying to win against somebody else, such as the Soviet Union. I personally think Congress will accept any solid acquisition strategy. There's not an a priori right or wrong approach; I really believe that. If DoD comes over, cogently explains its plans, and your analysis supports the recommendations, Congress is going to accept your proposal. By and large, you're going to get 97% of what you ask for. So, that's my feeble defense of the greatest institution on the face of the earth.

NUSSBAUM: It didn't sound feeble to me. We're nearing the end. Last call for rebuttals.

MCNICOL: I'd like to make an observation that may be particularly important for cost analysts. It seems that we've got three facts having to do with the work the cost community does on dual sourcing. First, the current acquisition statues put a heavy predisposition in favor of dual sourcing. Second, there seems to be in the Congress, in the Executive Branch, and in the public at large a growing skepticism about dual sourcing. Third, there may be some reluctance on the part of the Defense Department to use the provisions that are in the law to request a waiver from the dual-sourcing requirement. My guess is that Congress is not going to change the law. Hence, the cost community is going to find itself under increasing pressure to provide sharp analyses of the economics of dual sourcing as the bases for requests that we don't engage in dual sourcing for particular programs.

CARLSON: I'd like to add my "Yes" to that, especially for people down in the trenches who are designing these acquisition strategies and acquisition plans. We need to be able to use a decent model, as opposed to fear and superstition, in order to come up

with a reasonable economic analysis that can stand the tests that have just been mentioned by both the other speakers. There is a continual test of rationality as a program goes through the budget process and becomes a part of the President's budget. Also, what happens when it gets over on the Hill? We have to start with something that is cogent and reasonable with a firm analytical basis. In the past I don't think we've had that. There are lots of systems that we've second sourced without a firm analytical basis. We need to go back to those things that we actually have data on, recognize the assumptions we made, revalidate those assumptions, apply the data we have now that all the claims are in, and see if dual sourcing was, in fact, economic. We can identify those characteristics that you, as cost analysts, can capitalize on and project into the future, so that we have a reasonable, economic basis. I guarantee you that we did not have that in the past.

NUSSBAUM: Gentlemen, this is where I put my hat on as the timekeeper, but also on behalf of the assembled cost analysts at the Twenty-Third Annual Department of Defense Cost Analysis Symposium, I want to thank you for the insights on these very vexing problems which are slightly less vexing now that we've heard your views. I appreciate it, and I hope everybody joins me in showing their appreciation.

REAR ADMIRAL WILLIAM C. CARLSON, USN

RADM William C. Carlson was born in Detroit, Michigan in February 1937. He graduated with a Bachelor of Science Degree in Education and was commissioned through the regular NROTC program at the University of New Mexico in 1959. He subsequently was promoted to Rear Admiral (lower half) in December 1988.

He was initially assigned to USS AGERHOLM (DD-826), where he served as ASW Officer and then Weapons Officer. In 1962 he was assigned to the Naval Postgraduate School in Monterey, California, where he graduated in 1965 with a Master of Science Degree in Underwater Physics. In 1965 he was assigned as Commanding Officer of USS WHITE RIVER (LSMR-536), where he served until February 1968, during which time WHITE RIVER received two Navy Unit Commendations for her performance during five gunline tours off the coast of the Republic of Vietnam.

In 1968, RADM Carlson was assigned to the staff of Commander Antisubmarine Warfare Force, U.S. Pacific Fleet as ASW Weapons Officer, where he remained through 1970 when he was assigned as Executive Office, USS GOLDSBOROUGH (DDG-20). He served in GOLDSBOROUGH until December 1972 when he was ordered to command of USS SAMPLE (DE-1048), where he served until July 1974.

He then attended the Naval War College in Newport, Rhode Island, graduating with highest distinction from the College of Naval Warfare in July 1975. Following War College, RADM Carlson was assigned as Director, Sensors Division, Antisubmarine Warfare Systems Project Office in Washington, where he remained until June 1978. He then reported to the staff of Commander Carrier Group SEVEN, where he served as Surface Operations Office until February 1980 and then as Chief of Staff until May 1982. He reported to Naval Sea Systems Command in July 1982 when he was assigned as the first Manager, Surface Ship ASW Combat Systems Program (PMS411) where he served until July 1988 when he was ordered to the position of Assistant Deputy Commander for Antisubmarine Warfare and Undersea Warfare Systems at Naval Sea Systems Command.

RADM Carlson's awards include: the Legion of Merit; two awards of the Bronze Star with Combat "V"; the Meritorious Service Medal; the Navy Commendation Medal; the Combat Action Ribbon; two awards of the Navy Unit Commendation Ribbon; two awards of the Meritorious Unit Commendation Ribbon; Navy Expeditionary Medal; National Defense Service Medal; Vietnam Service Medal with seven campaign stars; Sea Service Deployment Ribbon with two stars; the Vietnamese Navy Distinguished Service Order (2nd Class); two awards of the Vietnamese Cross of Gallantry with Silver Star; the Vietnamese Meritorious Unit Citation (Gallantry Cross Color); and the Republic of Vietnam Campaign Medal. He is the Navy's 1987 recipient of the Department of Defense Superior Management Award for significant contributions to the defense effort.

RADM Carlson has three children: David, Scott, and Jennifer. David is a Lieutenant attending the Naval Postgraduate School in Monterey, California, Scott is a Lieutenant serving in USS WASP (LHD-1), and Jennifer is a recent graduate of the University of Michigan.

JOHN J. HAMRE

Employment Background

- Professional Staff Member, Committee on Armed Services, United States Senate (since May, 1984)

  Responsibilities include review of research and development and procurement programs under the jurisdiction of the Conventional Forces and Alliance Defense Subcommittee, budget issues, and relations with the Appropriations Committee.

- Deputy Assistant Director, National Security and International Affairs Division, Congressional Budget Office (from June, 1981 to May, 1984)

  Responsible for studies conducted on weapon systems and procurement programs for all the Military Departments, supervised a staff of 12 junior and senior analysts.

- Senior Analyst, National Security and International Affairs Division, Congressional Budget Office (from July, 1978 to June, 1981)

  Conducted studies in the area of strategic mobility forces and strategic nuclear forces.

Education

- Doctor of Philosophy (with distinction) from the School of Advanced International Studies, The Johns Hopkins University, June, 1978

  Emphasis in American Foreign Policy, International Economics and International Politics

- Harvard Divinity School, Harvard University, Cambridge, Massachusetts, September 1972-May 1973

  Studied systematics, theology and comparative religions as a Rockefeller Fellow.

- Bachelor of Arts (summa cum laude), Augustana College, Sioux Falls, South Dakota, June 1972

DAVID L. MCNICOL

POSITION: Deputy Assistant Secretary of Defense for Resource Analysis, Office of the Assistant Secretary of Defense (Program Analysis and Evaluation)

EDUCATION: A.B., Magna Cum Laude, Harvard University, 1966
M.S., Management, MIT, 1968
Ph.D., Economics/Finance, MIT, 1973

EXPERIENCE:

1982-1988: Director, Economic Analysis and Resource Planning Division, OSD (PA&E)

1981-1982: Deputy Assistant Administrator, Office of Applied Analysis, Energy Information Administration, Department of Energy

1980-1981: Director, Office of Economic Analysis, Office of Applied analysis, Energy Information Administration, Department of Energy

1977-1979: Senior Economist, Office of the Secretary, Department of the Treasury

1976-1977: Visiting Associate Professor, California Institute of Technology

1976: Senior Staff Economist, Council of Economic Advisors

1971-1975: Assistant Professor of Economics, University of Pennsylvania

HONORS, AWARDS AND SPECIAL ACHIEVEMENTS:

Presidential Rank Award (Meritorious)
Defense Distinguished Service Medal
DOE Special Service Award

PUBLICATIONS: Author of over 20 publications on commodity markets, regulatory economics, energy issues and economic aspects of the defense program.

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