Factors Affecting the Use of Competition in Weapon System Acquisition

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PREFACE

The use of competition in weapon system acquisition is widely advocated in policy statements issued by the Congress, the Office of Management and Budget, the Department of Defense, and the military services, but efficient and effective implementation practices remain poorly understood. There is a general belief that competition should be more widely utilized, but quantitative support for that belief is lacking.

In an earlier study[1] performed for the Office of the Under Secretary of Defense for Research and Engineering (OUSDRE), Rand presented some limited evidence suggesting that competition during the hardware development phase of acquisition was instrumental in reducing cost growth, but that the incidence of such competition had increased only slightly over the past decade. Rand then undertook for OUSDRE a follow-on study focusing on the incentives that may affect the extent of competition throughout the acquisition cycle. This report presents a policy-level overview of some factors that may be inhibiting more widespread use of competition, and suggests some changes in policy, regulations, and procedures. It also suggests additional quantitative research to provide acquisition managers with greater incentives to use competition, and to help them identify the circumstances under which competition is likely to pay off.

This report emphasizes the role of competition in the acquisition of full weapon systems, major subsystems and components. The results should be of interest to defense acquisition managers and policy-level executives.

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[1] Edmund Dews et al. Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s, Report R-2516-DR&E, October 1979.

SUMMARY

This study addresses the question of how the Department of Defense (DoD) might improve the effectiveness of competition in the acquisition of major weapon systems. The research approach was to examine incentives, disincentives, and uncertainties regarding competition as perceived by program managers and other senior DoD acquisition officials. This approach is rooted in the belief that competition can be used more effectively if acquisition managers have a clearer understanding of which kinds of competition are most effective and the circumstances in which competition is likely to be beneficial.

As a system moves through the acquisition cycle, the application of competition changes in two major ways: in the mix of benefits sought from competition, and in the cost of supporting such competition. Before the beginning of full scale development it is common to find competition among several firms over a combination of design concept, expected system performance and delivery schedule, and estimated costs. The investments required to achieve such competition are relatively small, and the benefits are generally perceived to be large. In contrast, true price competition is rarely found during the procurement phase. Here the manager is faced with two major disincentives: the introduction of competition will usually require added investment in the current year (with anticipated savings several years in the future), and the program is likely to be lengthened, incurring additional management effort and workload. The net effect of these disincentives varies from program to program, but they are rarely a trivial aspect of the manager's decision on whether or not to introduce competition during the procurement phase of a weapon acquisition program.

The justification usually postulated for introducing competition in procurement is the opportunity to achieve a lower unit production cost. Thus it is necessary to predict the effect on price that can be anticipated if competition is introduced. Unfortunately, the existing body of analysis has focused on past procurement of relatively small items (average unit cost less than $10,000), and it does not provide an adequate set of management tools for estimating either the dollar

benefits or the costs of competitive reprocurement. Furthermore, the literature indicates that much of the conventional wisdom about competitive reprocurement rests on shaky foundations, and that we may know less about competitive reprocurement than we thought we did. However, some conclusions seem warranted:

- Savings on electronic items reprocured competitively by the Army have been substantial, but we do not yet know to what extent these savings are dependent on (a) technological innovations in the electronics industry confined to a particular time period, (b) the Army's effective management of electronics acquisitions, (c) the relative ease of tranferring the necessary technology from one electronics firm to another, (d) the existence of a commercial market for similar items, which motivates producers to invest their own funds to ensure that the technology transfer process is successful, or any of several other explanations.
- A major decision in a competitive reprocurement is when in the production run to introduce the second source. Information currently available on earlier procurements yields little useful guidance on this point.
- While production costs tend to decrease with increasing quantities produced, suggesting that the original producer should be able to win a competitive award hands down, we find that more often than not the original producer loses when an item is reprocured competitively. But we do not know why. One earlier study presents some evidence suggesting that the profit weights for sole-source contracts, as defined in the procurement regulations, will motivate a profit-maximizing producer to set up a production process that is inefficient. Then, when this producer faces competition from a second source, he seems unable to shift to a more efficient production process.
- It is not clear whether competitive reprocurement pays off as a financial investment on systems as complex as missiles, because

there is as yet no evidence that internal rates of return are high enough to justify the drain on front-end funds.

- Data on competitive reprocurements are difficult to retrieve; and adequate, complete, and consistent data are almost non-existent. If data collection, storage and retrieval systems remain as they are, our quantitative understanding of the competitive reprocurement process is likely to remain weak into the 1990s.

We thus conclude that existing research provides neither quantitative nor qualitative guidance for designing price-competitive reprocurement strategies--one of the simplest, and certainly the most quantifiable, uses of competition. To correct this situation, further work is needed on methods for forecasting and evaluating the costs and benefits of various competitive strategies--not just the effect on price of competition in the reprocurement phase. Lacking such methodologies, program personnel are unable effectively to justify competition expenditures and the DoD is unable to develop criteria for selective application of competition. Further, without knowing how to evaluate competition in the context of acquisition, decisionmakers will tend to focus on the degree to which competition is or is not applied, instead of how much it has or has not increased the effectiveness of systems acquisition. The development of such methodologies will be neither simple nor rapid, given the difficulties of retrieving adequate information about past programs.

A simple but valuable first step would be to ensure that better records are retained on current competitive acquisition actions, so that future analysis can benefit from an adequate data base. Such a data base should enable analysts to focus on a broad set of characteristics of individual weapon systems as determinants of contract outcomes, as opposed to looking only at learning curves and cost relationships. The degree of technical sophistication and the advance it represents over the previous-generation system are potentialy important attributes. The role of the contract itself should also be considered in more detail. Even when contracts are classified as being of the same type, many aspects may vary widely, such as escalation clauses, penalties, award fees, payment ceilings, and so forth.

Finally, the underlying theory of how competion should function in weapon system acquisition seems to be inadequately developed. Research on the development and refinement of such a theory would be extremely valuable if it could provide a solid framework to guide the collection of data and the design of future data analysis.

ACKNOWLEDGMENTS

This research could not have been completed without the generous cooperation of many individuals throughout the Services, the OSD, the OMB, and Congressional staffs. We want especially to acknowledge the contributions made by senior members of the Project Offices we visited.

We are particularly indebted to our colleagues Allen Barbour, Geneese Baumbusch, Edmund Dews, Gary Massey, William Rogers, and John Rolph for their assistance throughout the course of the study, and to Jan Meshkoff for her able assistance in preparations for the interviews.

The final results and interpretations presented in the report must, of course, remain the responsibility of the authors.

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I. INTRODUCTION

In its 1972 report, the Congressional Commission on Government Procurement made recommendations ranging from the need for a "competitive" rather than a "maximum" number of sources at the proposal stage, to the role of competition in the later stages of system acquisition. The Commission dealt at length with what it perceived to be the need for introducing competition before the buyer had settled on a detailed technical approach to meeting an established requirement.[1]

After receiving the Commission's report in 1972, the Congress created within the Office of Management and Budget an Office of Federal Procurement Policy and empowered it to establish broad policy for governmental acquisition and procurement action. OMB Circular A-109, promulgated in 1976, encouraged design competition throughout the acquisition process and urged that non-competitive practice be the exception rather than the rule, especially in the early phases of acquisition before major resource commitments were made. The Circular also mandated that justification had to be provided to the Congress if competition was not used prior to full-scale development. Moreover, competition was explicitly allowed through development and procurement, with the objective in the later phases of acquisition apparently being focused on price reduction rather than the design excellence sought earlier.

In parallel with the broad policy initiatives of the Congress and OMB, policy analysts devoted considerable attention to the question of how competition could best be applied to the special problems of the Department of Defense. Any respectable scholarly study or Government-sponsored review of weapon system acquisition policies and practices during the 1970s was certain to include a section on competition.[2]

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[1] Report of the Commission on Government Procurement, U.S. Government Printing Office No. 5255-0000-, December 1972; see especially Vol. 2 (Part B--Acquisition of Research and Development; Part C--Acquisition of Major Systems).

[2] See, for example, J. Ronald Fox, Arming America (Cambridge, Harvard University Press, 1974), pp. 467-471; Electronics-X: A Study of Military Electronics with Particular Reference to Cost and Reliability (IDA Report R-195, January 1974), pp. 197-212; and the Defense Science Board 1979 Summer Study, Final Report.

Such studies generally have concluded that competition is a good thing and more competition would be better yet.

For more than 20 years, the DoD has attempted in various ways to increase the role of competition in the weapons acquisition process. Secretary of Defense Robert S. McNamara viewed procurement competition as a key element of the management innovations he introduced during the early 1960s. After Deputy Secretary of Defense David Packard became responsible for defense acquisition policy in 1969, he issued a series of memoranda that not only supported competition among developers involved in the creation of new hardware but extended the emphasis to include subsystems as well as full weapon systems. He instructed the three military services to adopt these memoranda as official policy and to modify Service policies accordingly. The eventual DoD Directive,[3] however, muted Packard's initial endorsement of competition.

The various OMB and DoD acquisition policy directives issued since then have generally emphasized competition during the earlier phases of development. OMB Circular A-109[4] advocates "competitive exploration of alternative system design concepts." However, competition later in the acquisition cycle is rarely mentioned, and then only advocated "whenever economically beneficial." No specific mention is made of competition during the production phase, nor is there any hint that such competition may be justified for reasons other than cost savings. DoD Directive 5000.1 and DoD Instruction 5000.2 repeat the same theme in slightly different words.

The military services are in at least formal compliance with OMB and OSD policy, and in some cases make an even stronger endorsement of competition. Army Regulation 1000-1[5] emphasized competition even before Circular A-109 became official executive branch policy. The 1975

[3] DOD Directive 5000.1, Major System Acquisition, 1971 (revised most recently in March 1980).

[4] Circular A-109, Major System Acquisitions, Office of Management and Budget, April 5, 1976.

[5] Regulation AR 1000-1, Basic Policies for Systems Acquisition, Headquarters, Department of the Army, April 1, 1978.

version of AR-1000-1 stated in part that the early stages of the development process. . ."should include fabrication and testing of competitive prototypes. . ." (Section 5a) and that programs should "assure contractor competition. . . [early] in full-scale production . . . based on a technical data package" (Section 5d). The Navy and Air Force made no independent directives with respect to competition, but attached DoD Directive 5000.1 to their own regulations, and endorsed its applicability.

With such an extensive body of policy directives issued over the past decade, could full implementation have been far behind? For the Department of Defense that question is surprisingly hard to answer, partly because the extent to which competition has actually been used in weapon system acquisition is difficult to determine,[6] and partly because of uncertainty about the circumstances in which competition is reasonable and desirable. Competition is actually mandated only for that part of the acquisition cycle that precedes the start of full scale development (FSD). After the start of FSD, competition becomes discretionary. Nonetheless, while the actual and the preferred extent of competition remain unclear, it is generally believed inside and outside the Department of Defense that more competition is needed and would be economically beneficial.

THE STRUCTURE OF COMPETITION

The quantitative evidence about the influence of competition on acquisition is subject to theoretical and empirical qualification, yet most observers argue that competition produces many significant benefits:

- Improved product quality.
- Lower unit costs.
- Faster rates of learning by the manufacturer.

[6] A description of the measurement difficulties is contained in White and Meyers, Competition in DoD Acquisition, Logistics Management Institute, Washington, D.C., May 1979.

- Greater technological progress.
- Enhanced industrial productivity.
- Enlarged surge and mobilization capacity.
- More equitable process of awarding acquisition contracts.

In light of such claims, it is important to consider what exactly is meant by "competition." In the context of systems acquisition, Hall and Johnson,[7] for example, chose to distinguish between pure price competition and competition which included non-price factors such as technical design. The former they called competition and the latter rivalry. From an acquisitions viewpoint, that distinction represents a clear categorization of factors on which to base competition, but it still suffers several problems. First, the distinction has not been widely accepted in the acquisitions community or in its literature, and second, very few cases arise which are not rivalrous. In most cases, factors such as system performance and delivery schedule play a key role in the competition for the contract. Thus, we consider the Hall and Johnson definition of competition too limited for use here.

In the economic literature, competition and rivalry also are key concepts, but in a somewhat different way than in the Hall and Johnson article. Competitive firms are those which have a very restricted ability to affect price or product characteristics or to undertake any strategic behavior. Rivalrous firms are those which undertake pricing strategies, new advertising, product development, and other actions which may greatly enhance their market positions. From this viewpoint, virtually all weapon system acquisitions would be considered as rivalrous rather than competitive. Again, however, that concept also is not used in the acquisition community and would lead to confusion if used here.

Furthermore, in the government's acquisition of major systems, subsystems, and technologically sophisticated components, the market differs from the economic structural ideal in several essential ways:

[7] G. R. Hall and R. E. Johnson, A Review of Air Force Procurement, 1962-1964, The Rand Corporation, RM-4500-PR, May 1965.

(1) the final products do not exist at the time developers are selected, and they usually do not exist in final form when producers are selected; (2) there are very few buyers for these products (although it is an error to view the "marketplace" as always having only one buyer); (3) the buyers have very imperfect information concerning the prices and functional specifications of the product, their own need for the product (i.e., the threat is uncertain and changing), and the relevant budgetary constraints, especially in future years; and finally, (4) the entry and exit of firms in this market is often slow and costly.

To avoid confusion among the several concepts above, we will use the term competition in its broad, generic sense. Any acquisition arrangement that requires more than one firm to compete for a particular contract will be called competitive. When we consider competition in development or production, in price or non-price factors, or in other cases, it will be noted. Further, contracts that do not allow direct competition will not be considered competitive (for example, sole-source follow-ons to competitive contracts, awards in response to unsolicited proposals, multiple sole-source contracts, and so forth).*

A careful reading of Congressional testimony leads one to suspect that in the legislative context the term "competition" usually implies "price competition." But the use of price competition is uncommon (at least since the total package procurement approach fell into disfavor). True price competition, unaffected by non-price elements, does not generally come into its own until the reprocurement phase--after at least one full-scale production run, and even then factors other than price are usually included.

When discussing competition or recording procurement actions as competitive, the DoD is typically referring to forms of non-price competition. During source selection for a development program, competing proposals are evaluated for technical and design features. Price proposals also may be weighed, but the final price is almost always negotiated after the source selection.

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* These may have outcomes as if they were competitive contracts and thus may be propely classified as such. For analytic simplicity, we remain with the above definition.

Figure 1 depicts the several types of competition that may be employed when acquiring weapon systems. Along the bottom of the figure we indicate the sequence of stages by which a major system is created and deployed--from concept formulation through development (prototype and full-scale) to production and procurement. The ways in which competition (over design or price or both) may be encouraged can be seen for each vertical segment representing a stage of the acquisition process.

During concept formulation, competition may concern only the design, as is often the case in the kind of R&D activities funded by the Defense Advanced Research Projects Agency, or (more commonly) both design and price. At this point treating competition as "principally" concerning either design or price can be quite misleading.

During the demonstration and validation phase, competition generally focuses on both design and price. The design specification typically is not yet fixed, and opportunities still exist to trade performance for price (such tradeoffs may, of course, take place in the context of what the DoD calls a "design-to-cost" goal). Competition among contractors may still be achieved by the buyer through the use of competitive hardware demonstration programs. The Air Force's Lightweight Fighter program (prior to selection of the F-16A for full scale development) is an example.

During the full-scale development phase, competition may be retained through the use of a second source (as in the case of the Army UH-60 helicopter). Otherwise, sole-source development may be completed and a second source qualified after an initial "learning buy." However, such reintroduction of price competition may be costly for the buyer if he has not anticipated it in his original acquisition strategy.

"Breakouts"* for second-sourcing of subsystems and components during production also have occurred, sometimes to achieve better price or quality and sometimes to ensure an adequate industrial base. Although the data are quite imperfect, the dollars committed by the

* In this acquisition strategy, the competitive acquisition of a subsystem or component is managed directly by the Service Project Office, rather than by the prime system contractor.

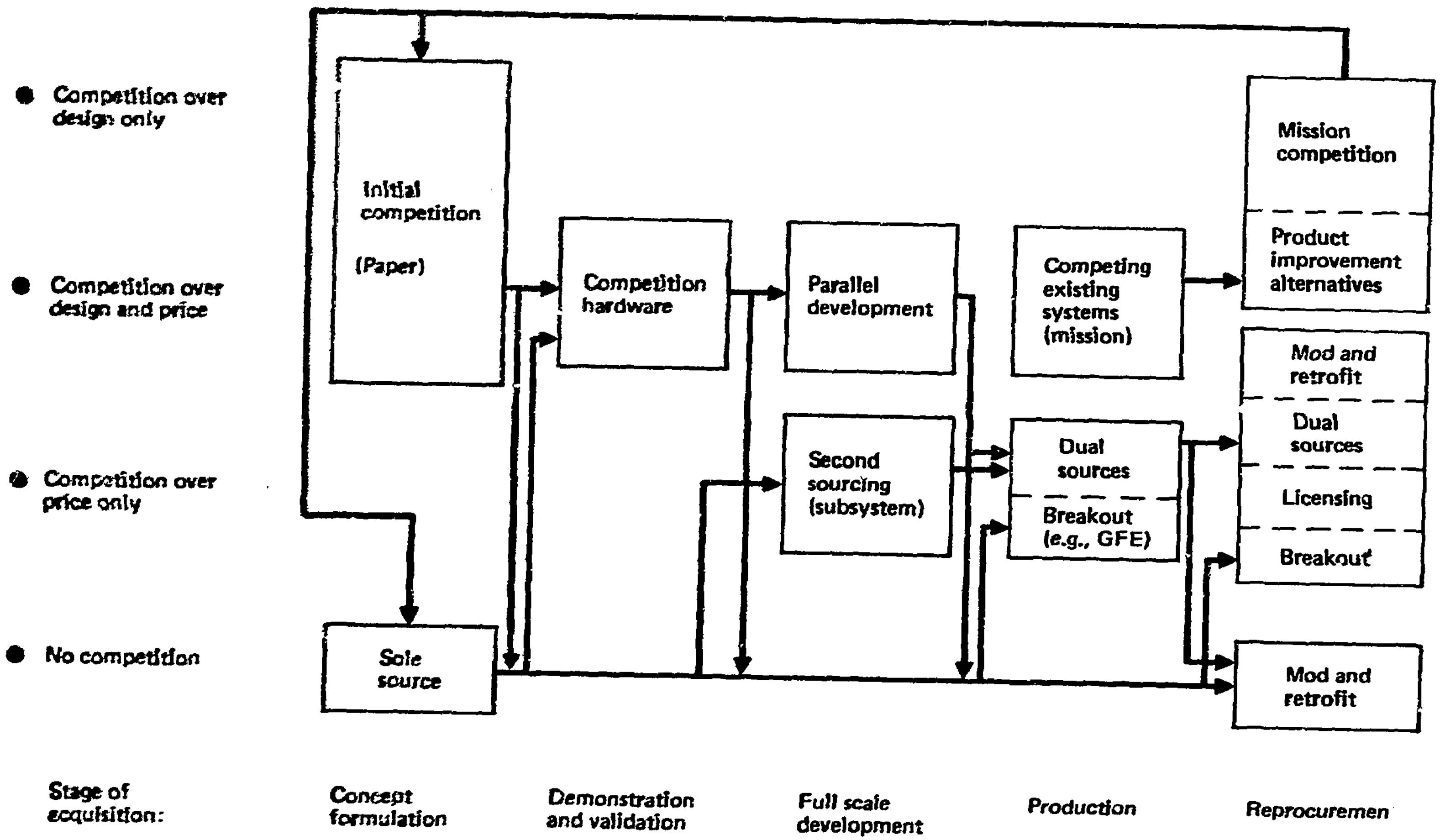

Fig. 1—Types of competition

Federal Government for such competitive breakouts probably have not amounted to more than 10 or 15 percent of total procurement funds for major systems. Of course, the prime contractor on a major weapon system may obtain competitive bids from its subcontractors and suppliers at the outset of a development program. Depending on the type of hardware involved, the prime contractor may continue to use price competition for some portion of his annual purchases. The benefits to the Government of maintaining that competitive environment vary with contract type and with the susceptibility of the contract to modification in the course of the program.

For most acquisition programs, existing systems compete for the same mission as that planned for the new weapon system. Thus, at various stages during the production or reprocurement process, competitive options exist which do not involve a single acquisition program, but instead involve product improvement alternatives based upon existing equipment. Examples include the various versions of the F-4 and B-52 aircraft which survived the competition with other aircraft options. Competition of this sort, however, transcends the charter of individual program managers. Once hardware development has begun, such competition can be vigorous only at the level of the Service heads, the DoD, and the Congress.

The possibility of introducing effective price competition during the reprocurement phase is dependent on appropriate preparations having been made early in the program, while a competitive environment still exists. (The purchase of a Technical Data Package (TDP) will suffice in some instances; arrangements for technical assistance to and qualification of additional producers will be needed in others.) For certain electronic items, it appears that the purchase of a TDP during the development phase and an Invitation-For-Bid (IFB) competition after the first few sole-source production runs generated substantial unit-price reductions in the 1960s.[10] For such other items as missile guidance and control units, the necessary and sufficient conditions for the effective use of price competition in the reprocurement phase are less clear. For systems as complex as aircraft, those conditions are themselves complex and must be addressed very early in the acquisition cycle. Fusion-fission, leader-follower, and directed licensing are

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[10] See Sec. III for details.

three acquisition strategies which, if implemented appropriately, provide options for introducing competition in the production phase of major systems.[11] These are complex strategies, however, and we have little experience in their application to major weapon systems.

This overview of some of the major issues related to competition is included to provide a framework for the subsequent discussion of incentives and disincentives for effectively using competition. It suggests the following conclusions:

- Formal policy directives support the limited use of competition, although the exact types of competition, the focus of application, and the benefits expected are ambiguous.
- Competition may be employed to achieve benefits other than, or in addition to, price reductions.
- Numerous opportunities occur throughout the acquisition cycle for the judicious introduction and continuation of competition.
- It is difficult to measure the extent to which competition has actually been employed in weapon acquisition, but many believe that competition should be used more extensively.

STUDY OBJECTIVES AND APPROACH

The objective of this report is to suggest how the DoD might stimulate more effective competition in major acquisition programs. Impressed by the difficulty experienced by previous researchers in measuring the extent or the benefits of competition in weapon acquisition, we adopted a different approach: i.e., we attempt to identify the factors leading to the use or rejection of competition, in

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[11] Leader-follower and directed licensing are variations on a plan where one company develops an item and then provides the technical assistance necessary for a second company to produce it, thus establishing a competitive posture. In one version the developer (leader) is paid a fee for the technology transfer service, and in the other version the developer collects a royalty on second-source production. Fusion-fission, a relatively new technique, requires two firms to share the development task and then each sets up a full production capability and competes for production lots.

the belief that such information would yield insights on how to enhance the use of effective competition. What is sought here is a management perspective on competition, focusing on management as a decision process that selects from a variety of acquisition strategies, sometimes choosing competition, sometimes not. Issues to be addressed include how managers view competition, what problems arise, how serious they are, what benefits can be expected, and how the effectiveness of competition can be enhanced.

We undertook a series of interviews with key management personnel to learn how they currently perceive the benefits and costs of employing competition in the various phases of acquisition. Programs in the sample included aircraft (F-16, F-18), a helicopter, (AH-64) and other systems (Advanced Self-Protection Jammer (ASPJ), M-198 Howitzer). In addition, extensive review of background work on competition bolstered the empirical research. The results, however, must be taken as illustrative and tentative. No validation of the interviews was undertaken, and the sample of personnel and programs was small. Still, the results reflect the concerns of an important set of acquisition participants and provide insights and suggestions for improving the effectiveness of competition. These management perspectives are described in Sec. II.

We had planned, at the beginning of our research, to include a brief review of existing quantitative research on the savings achieved through competitive reprocurement. The topic has received considerable attention by others during the past decade, so we did not expect that it would be necessary for us to devote much effort to it. One consequence of our interviews and discussions, however, was the realization that key decisionmakers place little confidence in either the precision or relevance of such estimates of savings. We found grounds for this skepticism in the uneven quality of the quantitative work that has been done. Analysts working on the topic do not agree on the extent of savings realized on <u>completed</u> competitive reprocurements, or even on how such savings should be estimated. And when it comes to forecasting savings on <u>contemplated</u> competitive reprocurements, analysts do not even agree among themselves on whether it can be done, let alone on how to do it.

This uncertainty seemed to be a critical element in any attempt to foster the use of effective competition in defense acquisitions. If realized savings (or losses) on past competitive reprocurements cannot be measured with much precision, and the expected benefits (to be achieved several years hence) on prospective competitive reprocurements cannot be estimated with any confidence, then the known, near-term costs and risks of introducing competition may well appear prohibitive, and in some cases rightly so. We therefore undertook an extensive and critical review of the quantitative literature on competitive reprocurement; its implications for the use of competition are described in Sec. III.

Finally, in Sec. IV we summarize our results, state our findings, and offer recommendations on how to improve the use of competition in the acquisition of major weapon systems.

II. MANAGEMENT PERSPECTIVES

Acquisition policy-makers at the highest levels of the DoD and the Services strongly espouse the increased use of competition in system acquisition. However, whether competition is likely to be implemented to a greater extent depends, in part, upon how closely the anticipated benefits correlate with the fundamental objectives and perceptions of the acquisition managers. For example, does competition help a system to be deployed faster, minimize technical risks, develop a wider political base, help acquisition personnel get promoted, ease financial and administrative problems, or speed the advance of technology? Do program participants recognize and have confidence in the benefits of competition, based on sound evidence?

It is far from obvious that the answers to such questions invariably favor the use of competition. Thus, if we want to increase the effectiveness of competition it may be necessary to improve our understanding of how managers and other acquisition executives perceive the effects of competition and what actions might be taken to shift those perceptions in a direction favoring greater use of competition, where appropriate.

METHODOLOGY

To gain a better understanding of what program management personnel perceive to be the advantages and disadvantages of competition, we conducted a series of interviews with the Service people involved in designing and carrying out a program acquisition strategy in their Program Offices. The personnel in each case were either program managers or deputy program managers, along with key Program Office personnel. The programs, listed in Table 1, span all Services and represent a variety of system types. Interviewees were chosen on the basis of the variety of competition experiences they represent.

Questions were designed to assess the extent to which competition was used on the program, how it was employed, what the circumstances were, what factors and personnel were involved in the decision, and what

Table 1

PROGRAMS DISCUSSED IN THE INTERVIEWS

AH-64 Helicopter

LWF/F-16 Aircraft

HARPOON Missile

MAVERICK Missile

SPARROW Missile

F-18 Aircraft

Advanced Self Protection Jammer (ASPJ)

M-198 Howitzer

the consequences of its use were. The questions did not seek quantitative information, but rather insights into the difficulties and advantages of employing competition. Further, the emphasis was on full systems (although subsystems and components were discussed) in all phases of the acquisition cycle.

While the sample is small, the people interviewed were very familiar with their own programs, and frequently had a great deal of experience with weapon system acquisition. Thus, their descriptions are considered representative of widely held perceptions regarding the use of competition in acquisition programs.

The interviews explored four main areas:

- Experience with competition--description of how and why competition was used, and to what effect.
- Incentives and disincentives--perceptions of how competition supports or threatens the objectives and needs of individuals in acquisition management.
- Current climate--perceptions of who key figures are in setting acquisition policy and how effective certain policies have been.

- o Background and context--perceptions on objectives of the Program Office and its position in the acquisition hierarchy, what support was available, what contracting techniques were used, and what lessons were considered relevant for future program managers.

In addition to the Program Office personnel, we interviewed persons involved in Federal competition policy (OMB, Congress) in order to gain a higher level, policy-oriented perspective.

Several caveats should be noted. First, the authors have made no effort to verify all of the observations. For the purpose of examining the perceptions and motivations of acquisition participants, such verification was unnecessary. A mistaken belief in the disadvantages of competition can be a very effective barrier to its use.

Another caveat is that the views reported here were expressed by at least one of the top-level Program Office personnel interviewed, but not necessarily by all. It is unlikely that all would agree with all of the views, but most were expressed more than once. Further, since most decisions involved a balancing of perceived advantages and disadvantages, instances were found where similar applications of competition were viewed in conflicting terms by different managers. Thus, the objective of the work was to develop a cumulative impression of the managers' problems, recognizing that internal inconsistencies are bound to occur.

The following discussion of the perceived disadvantages of competition may appear to draw a dismal picture of its effects. This results from a focus on the negative effects, prompted by our interest in the perceived <u>disincentives</u> for competition. Most of those interviewed favored the use of competition, albeit with discretion and careful planning. Thus, the following discussion should not be interpreted as a critique of competition, but rather as an an overview of the perceived barriers to better use of competition.

RESULTS

The barriers to competition, as perceived by senior program acquisition personnel, may be summarized under three headings:

1. Additional time and money needed.
2. Extra management complexity and effort required.
3. Few near-term benefits and incentives expected with high confidence.

Each of these barriers, or disincentives, is discussed separately below. Throughout the discussion an attempt will be made to distinguish among different problems that arise during different phases of the acquisition cycle.

Time and Money

At almost every phase in the acquisition cycle, and for almost every kind of competition, additional current-year investment is required over and above what would be necessary for a sole-source award. During the planning phase such funds are relatively small in absolute terms, although large in comparison to the overall funds available in that budget category. More important is the fact that competition during the concept formulation and analysis phase is a well-established tradition, so that funding for multiple sources is relatively easy for a manager to obtain.

When the program moves to the full-scale hardware development phase, the magnitude of the funding required for a second, competitive source becomes large in both relative and absolute terms. Furthermore, while general statements supporting competition occur at every level in the defense establishment, this does not mean that everyone concerned with a particular program will be willing to put up the money for competition. When the funding required to support a second, competitive source reaches the level of tens or hundreds of millions of dollars, authorization will have to come from higher up the chain of command. This means that many people will have to be "sold" on the competitive action. At every level in the organization there will be some who are sympathetic to the request for funds, but others will see themselves as competing for the same funds. Some groups will tend to underestimate the difficulty of developing a particular system or have an interest in fielding it very quickly, and thus will resist competition during full-scale development as a waste of time and money. The situation is even more complex in multi-service programs where all the Services must agree to put up the extra money.

When substantial amounts of money are involved, the DoD and the Congress must be sold on the competition as well. When there is no great pressure for competition and when other acquisition initiatives are being emphasized, those agencies can be difficult to convince. Congress tends to dislike programs with heavy front-end cost, and other less obvious political problems sometimes intrude.[1] Also, funding requests are reviewed by four different Congressional committees which do not automatically coordinate their decisions, so each must be persuaded separately. It is not unusual for one committee to support a competition and another to delete the funds for it.

Further, once funding for a competition is approved, there is no guarantee that the funding will be maintained. Money for competitive development programs is a prime target in a budget squeeze. Even if high-level support for competition is gained when the funding is first made available, there is no guarantee that the support will continue. In the Services and in the DoD there are frequent changes in top-level personnel, and when new people take over they often change priorities. Written policy supporting competition remains fairly consistent, but interest in competition changes with personnel. The result is that it can be difficult to maintain all the funding necessary to conduct a competitive development program.

Competition can slow the program because of the time involved in testing and source selection or in qualifying a second contractor. Schedules can also lengthen because of the increased program complexity

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[1] See Michael D. Rich, Competition in the Acquisition of Major Weapon Systems: Legislative Perspectives, R-2058-PR, The Rand Corporation, November 1976

and increased bureaucratic involvement[2] caused by competition.

Because program costs tend to increase faster than general inflation, increased program length risks increasing cost. The risk of increased program length is itself a disincentive to competition because there is usually a strong desire to deploy the system as rapidly as possible.

During the production phase the funding required to qualify a second, competitive source appears to pose less of a problem, at least for less complex systems or components. Perhaps this is because by the time the program is in production all major conceptual issues have long since been resolved, and attention is more easily focused on the task of efficiently producing the system. Furthermore, there is some belief that clear evidence of financial benefit exists for competitive reprocurement (but see Sec. III of this report).

Extra Management Effort

A commonly mentioned problem with competition is that it increases the workload of the Project Office. This extra work stems from two sources. First, if a competition is to be beneficial, considerable planning for the competitive steps is necessary. The request for proposal (RFP) must be prepared and the source selection process must be designed. The Program Office must comply with certain regulations designed to ensure the fairness of the competition. This involves special security to deal with "competition sensitive" material, special reports, etc. It also introduces the possibility of lawsuits, disputes,

[2] Conventional management practices followed by most Program Offices do not seem to exploit the potential advantages of design or price competition. Even where true competition exists, and the competing firms have adequate incentives to perform at their highest possible level of capability, the Program Offices tend to "manage" each contractor as if it were a sole source. The occasional exception to this rule (e.g., the prototype phase of the Lightweight Fighter Program) have demonstrated that dramatically austere management practices can be successfully used by the Service Program Office under some circumstances. Adoption and general acceptance of management practices more suitable for dual-source development or production would tend to eliminate some of the arguments voiced by Program Office personnel against use of competition.

and charges of unfairness by contractors who lose, so the source selection must be carried out in a way which not only chooses the best design, but also raises a minimum number of questions about fairness. That is not an easy task, particularly because little information or guidance can be drawn from the experience of other programs. "Lessons learned" reports from other programs are rarely very useful. For the most part, the program manager must base his planning solely on his own experience. Some program managers need no more, but in other cases lack of information complicates planning.

If awards are granted to more than one contractor, each additional contractor that the Program Office must deal with usually means more work. This is especially true when cost-type contracts are involved and the Program Office must monitor the costs of each contractor.

Competition during the production phase introduces management complications of its own. Qualifying a second producer after production has begun can be a major effort. It is difficult and expensive to get a good technical data package (TDP) for the second contractor to use in starting production, and even more difficult to persuade the first producer to pass along to a competitor the benefits of his manufacturing experience. The program manager can choose to develop his own TDP, but for major programs this is almost impossible. Not all the Services have the in-house capability to develop a TDP, and without this it is difficult to judge the adequacy of a TDP. Even with a good TDP, it frequently takes a major effort by the Program Office to help the second source through all its technical problems and into production. In some cases, the second source never succeeds in producing a usable product. But even in those cases, the pressure on the first contractor may still make the effort worthwhile.[3]

Further, the Program Office must work with both contractors on such things as quality control and configuration management. It is generally difficult to get two contractors to produce systems and components with

[3] See the discussion of SRAM missile motor case production in Baumbusch, et al, *Appendixes to the Report on the Peacetime Adequacy of the Lower Tiers of the Defense Industrial Base: Case Studies of Major Systems*. R-2184/2-AF, The Rand Corporation, November 1977.

interchangeable parts. If they do not do so, the Program Office faces additional problems in spare parts procurement. Further, each additional production line means an additional set of non-recurring costs whenever there is an engineering change. Finally, if two production lines are created, the program manager must decide how hard to push each contractor in order to ensure the benefits of competition. If he pushes too hard, he runs the risk of driving one of the contractors out of the program. and then he is back in a sole source environment after all the work and expense of qualifying two contractors.

So, one factor in program managers' reluctance to introduce competition is the perception that it will make management of their program more difficult and increase their workload. Since very few program managers believe they have enough well-qualified people to cover the work of monitoring one source, they are reluctant to take on even more work or to complicate matters. (International programs such as the F-16 add another dimension of complication, not considered here.)

It should be noted that under special circumstances competition can reduce the management workload of a Program Office. If a development program is fixed price, and the prime contractor is obligated only to a "best effort," then the program manager can adopt a largely "hands off" management style, with competition substituting for a host of conventional Program Office management controls over the contractors. However, this acquisition form is rarely used, the Services preferring to retain considerable control over contractor actions even with the attendant management workload. Another possibility is for the prime contractor to act as the agent for the Government in organizing competition for stipulated subsystems or components, thus relieving the Program Office of most of the burden of managing competition.

The major problem with having the Program Office manage such lower-tier competitions is that they are heavily regulated. The Program Office is not as free to deal with suppliers as the prime contractor would be, and cannot be as "ruthless" in getting the best deal. In addition, the regulations can slow down the project and increase costs, as well as force the Program Office to deal with suppliers who are qualified according to the criteria, but are known to be not very capable. Also, some suppliers will not take part in a Government-conducted competition because they do not like dealing with the bureaucracy and the associated red tape.

Once a formal competition begins, the entire program is governed by regulations that do not apply in other forms of acquisition. This results in a reduction in management flexibility for the program manager. For example, the regulations can result in a competitive award to a prime contractor that the program manager believes will not produce a technically adequate product. The award criteria may not always screen out a technically deficient competitor. But in the absence of a formal competition, the program manager would have more authority in contractor selection. He may suspect, for example, that the firm is "buying-in" by bidding lower than its technical and economic resources reasonably justify, and is hoping to get increased funding through later contract modifications and follow-ons. Or, he may have enough experience with or information about the firm to justify doubts about its qualifications. The other source of constraint is that any act that affects one prime contractor must be reflected in treatment of all other contractors as well. Thus, the program manager occasionally finds himself having to operate in what he views as a non-optimal fashion.

Lack of High-Confidence Near-Term Benefits

Disincentives of the sort described above tend to limit a manager's enthusiasm for introducing competition in his project. What positive incentives exist to counterbalance the negative ones? Apart from exhortations in policy documents and the conventional wisdom that competition is good for everyone, there are few direct incentives for introducing competitive practices. A program manager is unlikely to be rewarded merely for introducing competition. Real cost reductions are difficult to prove and, in recent experience, are likely to be masked by inflation. Moreover, given a typical tenure of only about three years, a program manager is unlikely to be around to receive the credit for any benefits that finally accrue. The costs of competition are short-term and clear, while the benefits are long-term and uncertain. The incentive structure is more likely to motivate the program manager to look for strategies that return short-term benefits.

Also, in many cases competition is seen as impractical. There may be few qualified contractors to participate in a competition and many of those may not wish to compete. Contractors often find that the uncertainties about how a competition will come out and about the criteria to be used in the source selection are sufficient to deter them from entering a competition. Qualifying a second source can be seen as impractical because the production run is too small, the tooling for the second production line is too expensive, or the design is too complex to be transferable. In the case of components, there simply may not be enough money involved to justify the cost of funding another source.

One commonly expressed view on competition is that the potential benefits are difficult to achieve because of the way acquisition is currently conducted. During a development-phase competition the major problems are perceived to be the too-early termination of the competition. One school holds that the ideal way to conduct a competitive development would be to keep two contractors in the program until the design is set and all decisions about the production schedule have been made. This would allow the Program Office to negotiate contracts with fairly firm prices and with production options that keep the prices fairly stable through the production run. It also would maintain the price benefits of the competition after the competition has ended. Further, it would help to set the design while competitive pressure still could be focused on the contractors, thus encouraging their best design efforts.

But that is not the way competitions tend to be conducted. Often the competition ends before the risks are resolved and the production contracts are fully set, with major design changes (and their associated cost increases) still to be expected. The price benefits expected from the competition may thus be lost. If design changes are made after competition has ended, either to deal with residual technical problems or to add capabilities, then any contracts will have to be renegotiated in a sole source environment. Prime contractors and sub-contractors will be less willing to accept low prices in a sole source environment than in a competitive environment.

OVERVIEW

Thus far, this section has been devoted to a review of problems and disincentives regarding the use of competition in the acquisition of major weapon systems. At this point we turn to a somewhat more speculative attempt to synthesize that information and put it into a broader context so that we can interpret it and suggest some remedies. Because of limited and incomplete information the following ideas must be characterized as hypotheses rather than conclusions.

We first observe that managers seem quite willing to employ competition among firms prior to the beginning of full-scale development, but generally are reluctant to establish price competition during production. The reasons seem rather obvious: each is the path of least resistance. The idea of receiving proposals and bids on a new item from multiple competitors is firmly and deeply engrained in our institutions, and it is relatively inexpensive. Despite all the work involved in preparing bid packages and performing source selections, it is probably easier than obtaining approval for sole-source negotiations, and that becomes more and more true as the size of the project increases. Note that we are here talking about competition before the beginning of full-scale development, where the selection criteria involve some subtle blend of design concept, perceptions of risk, and estimates of system performance, delivery schedule, and cost. While the formal source selection board will usually establish relative weights for those and other criteria, the final selection is actually performed by a few senior officials and is based on a highly intuitive blend of such factors. Although the benefits are not easily measured, most managers are comfortable with this process and are convinced that such competition produces a "better" product because it encourages each competitor to use his best people and to work very hard.

In contrast, consider price competition during the procurement phase. Here the problems and disincentives described earlier loom relatively large; the introduction of competition may significantly complicate program management tasks in a variety of ways. These bureaucratic problems can be extremely subtle and complex, and the present study has been able to barely scratch the surface. We are persuaded, however, that such problems play a significant role in the extent and success of competition in weapon acquisition and that they deserve more careful analyisis.

These institutional disincentives are compounded by the fact that managers have cause to be genuinely skeptical about the payoffs to be obtained. This skepticism takes three forms:

- Doubts as to the evidence that any significant savings were in fact obtained when price competition was introduced in previous reprocurement actions.
- Even if there is some evidence that savings were achieved in the past, doubts as to the likelihood that savings can be achieved "now" if price competition is introduced for the particular procurement action being considered. In other words, skepticism about the guidance available for identifying those procurements for which competition is likely to yield significant net dollar savings. The more sophisticated the executive--the more he recognizes both the costs of introducing competition and the significance of discounting--the more skeptical he is likely to be.
- Even where savings or other benefits seem achievable, the program manager often doubts that the proposal for competition can be sustained through the many layers of the management structure, especially because the required front-end funding may be competing with another program's very survival.

If this broad hypothesis is true (and we believe the evidence supports it), then two implications are clear:

1. Little or no additional incentive is needed to encourage active competition during the concept formulation and the demonstration and validation phases of a new weapon system.

2. Managers would have stronger incentives to employ price competition during the procurement phase (together with the necessary investment during hardware development and testing) if they had (a) evidence that it will in fact yield net savings (after accounting for all costs), (b) practical guidance on how to select promising candidates for price competition and how to structure an acquisition strategy to best achieve expected savings, and (c) active support for the front-end funding of competitive actions within the budgetary process. Provided with such information and support, managers may find price-competitive procurements more attractive. Without such information, the more venturesome managers may try to introduce competition when their intuition and judgment suggest it might pay off, but cautious managers may find the obstacles insuperable.

III. PRICE COMPETITION DURING REPROCUREMENT

One of the disincentives to the use of competition in the development phase is that the costs are near-term and tangible, while the benefits are long-term and difficult to identify or measure. It is the mixture of design and price competition, characteristic of competitive development, that makes it so difficult to identify and measure benefits. To measure the benefits of competitive development involves comparing the price and the quality or performance of the winning system with the price and the quality or performance of the system that would have gone into production had there been no competition. It is difficult enough, as the research reviewed in this section demonstrates, to make a quantitative comparison on price alone; if quality and performance are also to be taken into account, the basis for comparison will be largely qualitative and possibly quite subjective.

If competition is introduced in the production phase, costs are again near-term and tangible, while benefits are in the future. But the future benefits are--or at least should be--somewhat easier to identify and measure because competitive production is usually price-competitive. If price competition is introduced after there has been sufficient sole-source production to establish a learning curve,[1] then any difference between the post-competition price and the anticipated sole-source price for the same quantities can reasonably be attributed to competition, assuming that other aspects of the program remain reasonably constant or that their effects on price can be estimated. This is an important assumption and one that does not always accord with the realities of competitive procurement.

[1] A learning curve is a graphical representation of the relationship between the cost of producing an extra unit and the cumulative quantity already produced. Such curves usually have a negative slope; i.e., the cost of producing, say, the 200th item is less than the cost of producing the 100th item. Learning curves are usually graphed on a log-log grid because in logarithmic form the curve can be represented as a straight line.

Competition is sometimes introduced in the production phase for reasons having nothing to do with price; the decision to reprocure a system competitively may be motivated by a desire to improve performance or contractor responsiveness, viz. the Sparrow AIM-7F.[2] Even when the primary motive for turning to competitive reprocurement is an interest in lowering prices paid by the Government buyer, the introduction of competition can affect things other than price. In particular, the change from sole-source to competitive reprocurement may affect both the delivery schedule and the performance or quality of the items delivered.

Quality and delivery schedule are critical to system effectiveness, although analysts making cost comparisons between alternative system procurements have usually assumed that each procurement provided the same or very nearly the same item at the same or very nearly the same time. The real world is seldom that neat. In principle it is possible to adjust savings estimates to reflect differences in quality and delivery schedule; in practice, however, it is very difficult. The problems are similar to those involved in evaluating the benefits of development competition.

Thus, while there are opportunities to measure the benefits of competition in the production phase, these opportunities are, for the most part, limited to measuring the dollar benefits of competition in the reprocurement phase. These effects are the most quantifiable of all the effects of competition; nevertheless, it is not a simple task to develop reliable estimates of these effects.

The need to predict the price reductions attainable from competition derives from the fact that (for other than off-the-shelf items) there usually are substantial additional costs associated with introducing additional producers. These include the costs of transferring production technology: the costs of Technical Data Packages (TDPs), technical assistance, learning buys, and, not infrequently, subsequent claims against the Government for faulty TDPs or other inadequacies in the technology transfer process. These technology transfer costs are usually borne by the Government. Additional start-up

[2] See Daly, Gates, and Schuttinga (IDA79), App. B.

costs are often, but not always,[3] incurred by the Government buyer when a given quantity of an item is produced by more than one firm. These additional start-up costs include the duplication of tooling, overhead costs, and work-force learning.[4]

There also are added internal costs to the Government in conducting the competitive selection process (advertising, briefings, evaluating bids, etc.) and in managing a competitive production environment. It may sound contradictory to speak of "managing" a competitive production environment, given that one of the purported advantages of fixed-price competitive awards is the reduction of DoD's need to monitor costs incurred during the production process. While costs and the correct application of profit weights to various factors of production need not be monitored, Program Offices handling a competitive reprocurement may nevertheless discover--to their chagrin--other managerial tasks needing attention. These include second producers that default on their contracts without ever delivering an item, as happened twice, for example, during the Army's attempt to reprocure the PP-4763/GRC power supply competitively [APRO78, pp. 56-58]. Managerial problems also include companies which, after winning a competitive award, fail to deliver on schedule and subsequently blame the Government buyer both for the delays in the delivery schedule and company losses on the contract. For example, in the case of the PRC-77 radio set, a company submitted a claim for $10,721,728 alleging "increased costs for everything from specific design defects to lost profits due to the Mexican Peso devaluation in September 1976" [APRO78, p. 40]. Thus the managerial

[3] If the quantity per month to be reprocured is sufficiently greater than the quantity per month procured under the original sole-source contract so that a second production line would have to be set up anyway, then most of these additional start-up costs would have to be incurred with or without the introduction of competition and should not be debited from the savings attributable to competition.

[4] The effect of work-force learning, and other factors reflected in learning curves, on price reductions attainable from competitive reprocurement has received considerable attention. In fact, as we point out later, reliance on production-cost learning curve theory as a key explanatory model when examining competitive reprocurement appears to have been excessive. Rather than the theory explaining the findings; more often than not, the findings contradict the theory.

burden experienced by a Program Office is not always eased as a result of having reprocured an item competitively.

For competition to have a net dollar payoff, the sum of all these costs must (at least) be offset by price reductions induced by the competitive process. It is not enough simply to have faith that the competitive process will lower prices by some amount. A forecast of that amount is needed in order to judge whether gross savings are likely to be sufficiently greater than the costs of opening additional sources of supply to justify both the costs and the risks (of performance problems and delayed delivery) associated with competitive reprocurement.

In this section we (a) review the findings and conclusions reported in past studies of competitive reprocurement, focusing on work done for or within DoD in the 1970s; (b) examine some of the problems involved in estimating the dollar benefits realized from competitive reprocurement in the past and in predicting the price reductions that might be attained from the use of competitive reprocurement strategies under varying conditions in the future; and (c) discuss some of the implications of these findings and problems.

We focus most of our attention on four relatively comprehensive studies done for or within DoD: a 1972 study by the U.S. Army Electronics Command (ECOM72), a 1974 study by the Institute for Defense Analyses (IDA74), a 1978 study by the U.S. Army Procurement Research Office (APRO78), and a second, more recent (1979) study by the Institute for Defense Analyses (IDA79).

THE FOUR KEY STUDIES: ECOM72, IDA74, APRO78, and IDA79

Quantitative research in the 1970s concentrated on several distinct tasks. One is a statistical task which involves developing a model to predict price changes attributable to competition. ECOM72 was interested only in this predictive task; the three more recent studies tackled other tasks as well. Chief among these other tasks in our opinion--although not necessarily in the opinion of the authors whose work we review--is what we shall refer to as the accounting task. The accounting task concerns itself with "the bottom line:" what is the appropriately discounted net dollar payoff[5] from an investment made to introduce competition in the reprocurement phase?

Only APRO78 and IDA79 addressed the accounting task explicitly. APRO78 emphasized the importance of including the costs incurred by the Government buyer before, during, and after the introduction of competitive reprocurement, i.e., the importance of examining <u>net</u> rather than <u>gross</u> savings. IDA79, on the other hand, emphasized the importance of discounting, i.e., of taking into account the time value of money by estimating the net present value of and/or the internal rate of return from investments made to introduce competition during reprocurement.[6]

We introduce each study by describing its objectives, the 'sample'[7] of competitively reprocured items analyzed, and the key findings and conclusions related to price competition in the reprocurement phase.

<u>The First Study: ECOM72</u>

This study by the Cost Analysis Division of the ECOM Comptroller's Office set out "to determine if a predictive model or methodology could be established"[p. i] to forecast unit-price reductions from competitive reprocurement.

The ECOM72 analysts, limiting their search to electronic items managed by ECOM, were able to find price data in 22 instances of competitive reprocurement. They found data on quantities, lead times,

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[5] The savings that result from competition accrue over time sometimes many years removed from the investment. Hence, discounting to net dollars is needed to indicate the true economic consequences of the investment.

[6] On discounting, net present value, and internal rates of return, see Fisher (1970), pp. 217 et seq.; Hirshleifer (1958); McKean (1958); and Shishko (1976).

[7] The word 'sample' is enclosed in single quotes throughout to signal that these are not samples in a formal statistical sense. This means that it is difficult to make inferences about other competitive reprocurements from the results obtained by analyzing these potentially non-representative instances of competitive reprocurement.

Throughout this section, we also distinguish between the 'samples' used for statistical analyses and the existing data base. Each study collected data on items which were not, for one reason or another, included in its 'sample.' Such items are sometimes picked up by a subsequent study and included in its 'sample.' See, for instance, Table 2.

and delivery schedules--the predictor variables of interest to ECOM72--for only 13 of the 22 cases. Table 2 lists these 22 items, along with their sole-source and post-competition unit-prices, and indicates which of the items were used in the ECOM72 'sample' and which have been used in subsequent 'samples.' These items first entered production between FY 1958 and FY 1967.

ECOM72 looked at unit-price reductions on, in almost every case, the first competitive buy. All ECOM72 first buys were buy-outs.[8] The reported arithmetic mean of unit-price reductions, not adjusted for inflation or learning effects,[9] was 54 percent on the data base of 22 items, with a standard deviation of 15 and a range from 12 to 78 percent.

On the 'sample' of 13 items used in ECOM72's attempt to develop a "predictive model or methodology," a mean unit-price reduction of 53 percent is reported. ECOM72 reported unit-price reductions on individual items only for this subset of 13; Table 3 ranks these items by unit-price reduction.

The ECOM72 analysts used multiple regression in their attempt to develop a model that would predict unit-price reductions. They used three ratios as predictor variables: competitive lead time over sole-source lead time, competitive quantity over sole-source quantity, and competitive delivery rate (quantity per month) over sole-source delivery rate. They concluded that none of the regression equations examined were good candidates for a predictive model, and that

> To further pursue the attempts of finding more significant causal relationships among lead time, quantity, and delivery by regression techniques appears futile. It can almost be concluded that the desired relationship is severely clouded by the other variables that would be difficult to quantify. Also,

[8] We use the term "buy-out" to refer to awards that go to one producer, i.e., to distinguish from a split-buy. The term "winner-take-all" will be used to refer to a buy-out that is intended to include all future quantities of the item.

[9] IDA79 derived learning curves from prices on those ECOM72 items where there were at least two sole-source buys and found the curves to be so shallow that adjustment for sole-source learning has little effect on mean unit-price reduction. [p. 52]

Table 2

ITEMS IN THE ECOM72 DATA BASE BY UNIT PRICES AND USE IN SAMPLES

Items in the ECOM72 Data	Used in Which 'Sample'?				Sole-Source Unit Price Used by ECOM72(a)	Post-Competition Unit Price(b)
	ECOM72	IDA74	APRO78	IDA79	(then-year $)	
1. AN/ARC-54 Airborne Radio Set	x			x	5620.	1381.
2. Squad Radio: AN/PRT-4 AN/PRR-9	x			x	290.(c)	170.
3. TD-352 Multiplexer		x		x	9330.	3653
4. TD-202 Radio Combiner		x		x	4710.	1717
5. TD-204 Cable Combiner		x		x	4951.	1655
6. TD-660 Multiplexer		x		x	7931.	3234
7. MD-522A/GRC Modulator-Demodulator	x	x		x	2960.	1275.
8. AN/ARC-131 Radio			x		2975.	2132.
9. AN/UPM-98 Test Set	x		x		9130.	5150.
10. PP-4763/GRC	x				1095.	461.
11. MK-980/PPS-5	x			x	10658.	3718.
12. AN/APM-123 Test Set	x			x	6350.	2078.
13. AN/GRC-103 Radio Set	x			x	24404.	9995.
14. AN/GRC-106 Radio Set	x			x	15137.	6897.
15. AN/PRC-77 Radio Set	x		x	x	937.	487.
16. AN/PRC-25					2157.	843.
17. TD-206/G					460.	190.
18. AN/FLR-9					(d)	(d)
19. S-250/G Shelter	x				3826.	1827.
20. AN/FYC-8X					12630.	7110.
21. CV-1548 Signal Converter	x	x		x	3546.	1440.
22. AN/ASN-43	x				2055.	1800.

SOURCES: ECOM72, pp. 7-8, Apps. I and III; IDA74, p. H-3; APRO78, p. 66; IDA79, pp. A-4.

(a) Sole-source prices used by ECOM72 are not adjusted for learning effects. Nor are they always the prices from the last sole-source buy before competition.

(b) For items used in the ECOM72 'sample,' post-competition prices reported by ECOM72 on p. A-1 are used. For other items, the price or average of prices reported on pp. C-1 to C-4 are used.

(c) The average of the two sole-source prices which ECOM72 indicates were used (p. C-1) is 286.

(d) Not available.

Table 3

ITEMS IN THE ECOM72 SAMPLE WITH UNIT PRICE
ON FIRST COMPETITIVE AWARD, ORDERED BY UNIT-PRICE REDUCTION

	Item	Unit-Price Reduction (not adjusted for inflation or sole-source learning) (percent)	Unit-Price, First Competitive Buy (then-year $)
1.	AN/ARC-54 Airborne Radio Set	75.	1381.
2.	AN/APM-123 Test Set	67.	2078.
3.	MK-980/PPS-5	65.	3718.
4.	CV-1548	59	1640.
5.	AN/GRC-103 Radio Set	59.	9995.
6.	PP-4763()/GRC	58.	461.
7.	MD-522A/GRC	57.	1275.
8.	AN/GRC-106 Radio Set	54.	6897.
9.	S-250 Shelter	52.	1827.
10.	AN/PRC-77 Radio Set	48.	487.
11.	AN/UPM-98()	44.	5150.
12.	Squad Radio: AN/PRT-4 AN/PRR-9	41.	170.
13.	AN/ASN-43()	12.	1800.
	Arithmetic Mean =	53.	

SOURCE: ECOM72, pp. 7-8, Apps. I and III.

> the number of . . . items making the transition from sole-source to competition each year is small, and to accumulate a large enough sample to provide sufficient degrees of freedom if the variable list were expanded would span many years. [p. 22]

The sole objective of this study was to determine if a predictive model could be developed. Having decided that it would be very difficult, if not impossible, to develop such a model, the authors state in their closing paragraph:

> The only conclusions that can be drawn from this study are that unit price is substantially reduced by competition--possibly more than was thought--and that the difficulties that might be voiced and thought to exist when dealing with the problems encountered by the new awardee are well worth the effort in dollars saved. Also, use of the 25-30% reduction for planning purposes appears very conservative. Larger reductions for systems consisting of a good mix of major items could approach 40-50% with some degree of confidence since very few occurrences were noted below this range. [p. 24]

The Second Study: IDA74

This study by Zusman et al. was conducted for the Advanced Reseach Projects Agency (ARPA). It included three tasks, only one of which concerns us here: an examination of competitive reprocurement "to measure quantitatively the effect of competition on selling price." [p. 45]

The IDA74 team contacted 22 principal agencies within DoD, and 47 divisions or offices within those agencies, in their search for data--a search that turned up usable data on only 19 items.[10] The criteria for inclusion of an item in the IDA74 'sample' were not overly demanding: "retrievable price (not cost) data," "at least two sole-source production awards," "at least one competitive award," and a "unit cost of at least $1000." While there are only 19 hardware items in the IDA74 'sample,' the authors used 20 instances of competitive reprocurement in their analysis. They used the Bullpup twice: as a competitive split-buy won by Martin and as a winner-take-all award won by Maxson (See Table 4)

[10] This search is described in IDA74's App. G.

Table 4

ITEMS IN THE IDA74 SAMPLE WITH UNIT PRICE ON FIRST COMPETITIVE AWARD, ORDERED BY UNIT-PRICE REDUCTION

	Item	Unit-Price Reduction (percent)	Unit-Price, First Competitive Buy(a) (1970 dollars)
1.	MD-522 Modulator-Demodulator	60.3	1275.
2.	TD-352 Multiplexer	57.8	4291.
3.	Aerno 60-6402	57.0	3030.
4.	CV-1548 Signal Converter	53.7	1503.
5.	MK-48 Warhead	53.2	5087.
6.	TD-202 Radio Combiner	52.5	1741.
7.	TD-204 Cable Combiner	50.2	1877.
8.	TOW Missile	48.1	1999.
9.	Bullpup (Maxson)	45.8	1474.
10.	Talos Guidance and Control	42.3	87636.
11.	MK-48 Electric Assembly	37.5	6027.
12.	USM-181 Telephone Test Set	36.0	422.
13.	APX-72 Airborne Transponder	32.6	1653.
14.	FGC-20 Teletype Set	32.0	1308.
15.	TD-660 Multiplexer	30.2(b)	3524.
16.	SPA-25 Radar Indicator	21.3	6819.
17.	Bullpup (Martin)	13.8(b)	3725.
18.	Hawk Metal Motor Parts	6.4	1014.
19.	Rockeye Cluster Bomb	5.3	1641.
20.	Shillelagh Missile	-0.2	3041.
	Arithmetic Mean =	36.8	

SOURCE: IDA74, Table 10, p. 56 and Table H-0, p. H-3.
(a) More or less the first competitive buy; see text.
(b) Last digit not clear in our copy of IDA74.

These 20 instances include six items from the ECOM72 data base, two of which were used in ECOM72's regression analysis. Most of the items in IDA74's 'sample' were procured by the Army.

IDA74 examined unit-price reductions on the first competitive buy, as did ECOM72, but for the TOW and the second Bullpup case (Maxson), the first buy-out following competitive dual-sourcing was used. For the first Bullpup case (Martin), the Rockeye cluster bomb and the Shillelagh, the first competitive buy used is a competitive split-buy.

IDA74 used constant (1970) dollars to control for inflation and adjusted for sole-source learning effects by extrapolating an expected sole-source price from a learning curve based on unit prices.[11] The arithmetic mean of the unit-price reductions on the first competitive buy as defined by IDA74 is, for this group of mostly Army electronic items and missiles, 36.8 percent. The median is 39.9 percent.

IDA74 used multiple regression analysis to examine the effect on post-competition unit-price reductions of four variables: the exponent of the sole-source learning curve, the ratio of competitive to sole-source quantities, "type of competition," and number of bidders as a measure of "the intensity of competition." The effect of the number of bidders was not statistically significant. IDA74 does not proffer the regression equation derived as a predictive tool; the authors merely

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[11] The derivation of sole-source learning curves from price/quantity data points, rather than production-cost/quantity data points, is the rule rather than the exception in studies of competitive reprocurement. IDA74 offers the following justification for this practice:

> While progress (production-cost learning curve) theory is based on a relationship between cost and quantity, it was found that the only data available to us were price data. Under a sole-source contract, where the government is monitoring the contractor's costs, marginal costs and marginal prices are highly correlated; and it is expected that progress theory will accurately reflect price behavior. Therefore, we have referred to the sole-source price-quantity relationships as progress curves. (Emphasis in the original.)

Among the four studies we focus on, only APRO78 used production costs rather than prices in estimating learning curves.

summarize the nature of the three statistically significant relationships. (1) "The steeper the progress-curve slope the less that is likely to be saved." (2) On the first competitive buy, maximum savings are achieved with a buy-out competition, minimum savings with a 50/50 split-buy (each competitor gets half of the total). The authors caution that if "there are additional buys after the first competitive buy, then a (buy-out) strategy may not be optimum." (3) Unit-price reduction is negatively correlated "with the ratio of the number of units bought under the first competitive award to the total number of units produced under all the sole-source awards." [p. 59]

A negative correlation between unit-price reduction and the ratio of the first competitive quantity to sole-source quantity was also reported by ECOM72. IDA74's replication of this finding on a more varied set of items is interesting given that production-cost learning curve theory, conventional wisdom, and the DAR[12] lead one to expect a positive correlation.

The Third Study: APRO78

Lovett and Norton of the U.S. Army Procurement Research Office wanted to "(i) develop a methodology to estimate the net savings achieved due to competition, (ii) further develop the methodology to forecast the net savings expected from introducing competition into the procurement of future major weapons systems, (iii) furnish an organized data base to support the net savings methodologies." [p. ii]

The APRO78 'sample' consists of 16 Army and Navy systems; three of these were also in the IDA74 'sample' (the Shillelagh, TOW, and Bullpup missiles) and two were in the ECOM72 'sample' (the AN/ARC-131 and AN/PRC-77 radios).

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[12] Section 3-108 on the Negotiation of Initial Production Contracts, Paragraph (d) states:

> The number of items to be procured under an initial production contract will be established only after considering all pertinent factors, including the practical minimum quantity suitable to permit the development of the production design and a data package adequate to establish competitive procurement of the item at the earliest practicable date. (Emphasis added.)

APRO78 was the only study to collect production-cost data. For systems on which such data were available, sole-source learning curves were derived from disaggregations of and adjustments to those data. To arrive at net savings, the APRO78 analysts also collected all the data they could find on the external costs of introducing competition. Those were primarily costs related to the transfer of production technology from one firm to another; technical assistance and learning buys for the second source are included, but not the cost of TDPs. Successful claims against the Government by the second source for faulty TDPs and the like are also included. Due to time constraints, the APRO78 analysts did not attempt to collect data on the in-house costs of competition, i.e., the additional expenses incurred by the Government buyer in setting up and managing a competitive environment. Thus their estimates of actual savings and losses are estimates of partly netted savings and losses.

These estimates of savings and losses were not discounted, nor were ECOM72's and IDA74's price reductions. They were savings or losses over all quantities after the first buy-out competition, including expected future buys. (Recall that IDA74's price reductions were on the first competitive buy only, whether that was a split-buy or a buy-out. ECOM72's were mainly on the first competitive buy, and all instances were buy-outs.) APRO78 reported, in FY 1972 dollars, these partly netted savings and losses as a percentage of what total procurement costs would have been if all procurement had been sole source.

These partly netted savings and losses as a percentage of total procurement costs are shown in Table 5.

APRO78 also computed average percentage unit-price reduction across all post-competitive-buy-out quantities, including, as in the estimate of partly netted savings, quantities budgeted for but not yet purchased. This figure is proportional to gross savings on these quantities. This measure of gross savings, also in FY 1972 dollars, was used in the multiple regression analysis conducted by the APRO78 analysts in their attempt to develop a predictive model. These results on gross savings are shown in Table 6.

Table 5

ITEMS IN THE APRO78 SAMPLE WITH PARTLY NETTED SAVINGS IN DOLLARS, ORDERED BY SAVINGS AS PERCENTAGE OF TOTAL PROCUREMENT COSTS

	Item	Partly Netted Savings/Losses as Percent of Total Procurement Costs	Partly-Netted Savings/Losses (millions of FY72 dollars)
1.	Shrike Missile(a)	51.0	103.2
2.	PRC-77 Radio	34.8	52.6
3.	TOW Launcher	30.2	83.5
4.	FAAR TADDS	18.2	2.0
5.	FAAR Radar	16.6	4.8
6.	Bullpup AGM-12B Missile(a)	16.0	38.3
7.	Dragon Tracker	12.0	12.2
8.	TOW Missile	8.5	61.3
9.	Shillelagh Missile	5.9	18.3
10.	UPM-98 Test Set	3.0	.08
11.	Dragon Round	2.7	8.0
12.	ARC-131 Radio	- 2.1	- .6
13.	Sidewinder Missile AIM-9D/G GCG(a)	- 2.7	- 1.9
14.	Standard Missile(a)	- 3.9	-11.8
15.	Sidewinder Missile AIM-9B GCG(a)	- 4.0	- 6.7
16.	Mark 46 Torpedo(a)	-13.2	-52.9
		Arithmetic Mean = 10.8	Total = 310.38

SOURCE: APRO78, Fig. 6-1, p. 93.
(a) System analyzed by Kluge and Liebermann, TRI.

Table 6

ITEMS IN THE APRO78 SAMPLE WITH AVERAGE UNIT PRICE ACROSS ALL POST-COMPETITION PRODUCTION

	Item	Gross Savings (percent)	Post-Competition Unit Price (1972 dollars)
1.	Shrike Missile(a)	52.8	6309.
2.	PRC-77 Radio	41.9	589.
3.	FAAR Radar	39.5	85805.
4.	TOW Launcher	34.7	17702.
5.	FAAR TADDS	31.1	2714.
6.	Bullpup AGM-12B Missile(a)	26.9	3202.
7.	TOW Missile	12.4	2114.
8.	Dragon Tracker	12.2	5935.
9.	UPM-98 Test Set	11.5	8676.
10.	Shillelagh Missile	9.4	2611.
11.	Dragon Round	2.9	1828.
12.	Sidewinder AIM-9D/G GCG(a)	.7	6748.
13.	Standard Missile(a)	- 5.4	46517.
14.	Sidewinder AIM-9B GCG(a)	- 5.5	2151.
15.	ARC-131 Radio	-16.1	3714.
16.	Mark 46 Torpedo(a)	-29.4	35785.
	Arithmetic Mean =	13.7	

SOURCE: APRO78, Figure 4-2, p. 68.
(a) Systems analyzed by Kluge and Liebermann, TRI.

The authors, Lovett and Norton, are somewhat cautious in their conclusions about the effects of price competition:

> Much has been written about competition and how it saves the Government money when introduced into weapons systems acquisition. Most of the studies claim substantial savings through reduced unit prices and attribute the reduction to competition. While this report supports the belief that savings have been made in the past and will continue to be made in the future through competition, it recognizes that competition does not always result in a savings to the Government, and that when savings do occur, not all the price reduction creating the savings is due solely to competition. A portion of the price reduction is due to contractor learning. It also recognizes the expenses incurred by the Government to obtain a competitive environment and identifies some of the problems that may be created by establishing competition. [p. 84]

In their attempt to develop a predictive model, the APRO78 authors checked several variables (they do not say which ones), and several different transformations (logarithm, square, square root, etc.). They ended up with a model in which the outcome variable was the logarithm of the price after buy-out competition, and the predictor variables were the logarithms of the expected sole-source price and the ratio of post-competitive-buy-out quantity to total program quantity.

Lovett and Norton were not, we believe, sufficiently cautious in evaluating the adequacy of their predictive model. They suggested the model can be used "to forecast a competitive bid price" [pp. 70,75] and "to determine the ratio of quantities at which the projected (sole-source) unit price equals the forecasted (competitive) unit price." [pp. 73,77] The authors cautioned that the "quantitative results derived (from this model) must be viewed in light of the qualitative factors which influence potential savings due to competition," [p. 77] and they presented two management tools for dealing with the qualitative factors: a "competition screen" to be applied before the model is used [pp. 63-67] and a "competition index" to be used after obtaining positive results from the quantitative model [pp. 77-81]. They recommended that the model be tested "on a system meeting the required competition structure to verify its applicability and accuracy" and, if verified, that the model be adopted by the Comptroller of the Army.

The Fourth Study: IDA79

This IDA project, partly overlapping the period of our own study, was conducted by Daly, Gates, and Schuttinga for the Office of the Under Secretary of Defense for Research and Engineering (Acquisition Policy). Its purpose was "to examine the benefits and costs of utilizing price competition during the reprocurement phase of the weapon system acquisition process and to determine: (i) when competition should be considered . . .; (ii) how long multiple sources should be maintained if competition is introduced; and (iii) the changes in policies and practices which would improve the use of competition." [p. S-1]

The IDA79 analysts, in estimating gross savings and in attempting to develop a predictive model, used data assembled by the other three studies. After discarding items for which there were fewer than two price-quantity data points [p. A-2], IDA79 was left with 31 items, as shown in Table 7. Included were the six electronic items that appeared in both the ECOM72 and IDA74 analyses; the three missiles included in both IDA74 and APRO78; four more missiles and the MARK-46 torpedo from APRO78; seven other electronic items from ECOM72; and ten asserted systems from IDA74, including two on which Zusman et al. collected data but discarded from their 'sample' because the unit prices were below $1000 (the Aerno 42-0750 voltage regulator and the Aerno 42-2028 generator). Thus this IDA79 'sample' of 31 includes more low unit-price items and more electronic items than either the IDA74 or the APRO78 studies. As shown in Fig. 2, over two-thirds of the 31 items had a cumulative average price of less than $10,000 at the end of sole-source production, i.e., when the price, especially the cumulative average price, was still generally high.

Although the IDA79 authors, in reporting results on actual savings, sometimes refer to "net savings" (in their Table 4, for instance), the only costs of competition netted out are "the contract costs of learning buys for the second source and split-award competitions." [p. 62] "Savings are calculated," we are told, "by subtracting the actual cost to the government (contract price) of all post sole-source production contracts from the price projected on the basis of the sole-source progress curve and then expressing the difference as a percentage of the

Table 7

ITEMS IN THE IDA79 SAMPLE, ORDERED BY GROSS SAVINGS

Item	Gross Savings on All Post-Competition Production (in percent)
1. CV-1548	64.0
2. TD-204	62.1
3. AN/APM-123	61.2
4. AN/GRC-103	58.7
5. MD-522	58.6
6. TD-352	58.0
7. USM-181	56.0
8. MK-980/PPS-5	56.0
9. ARC-54	55.0
10. Aerno 42-0750	54.8
11. Aerno 60-6402	49.4
12. SPA-25	46.8
13. TD-202	46.8
14. HAWK metal motor parts	45.7
15. TOW Launcher	44.2
16. AN/GRC-106	43.3
17. PRT-4	42.3
18. TALOS Guidance & Control	40.8
19. TD-660	38.3
20. Bullpup Missile	31.7
21. AN/APX-72	27.1
22. FGC-20	23.7
23. PRC-77	20.5
24. Aerno 42-2028	19.9
25. Rockeye Cluster Bomb	11.6
26. TOW Missile	8.9
27. AIM-9B Guidance & Control	1.6
28. Standard Missile	- 4.2
29. AIM-9D/G Guidance & Control	- 4.6
30. Shillelagh Missile	- 8.0
31. MK-46	-23.0

	Arithmetic Mean = 35.1

SOURCE: IDA79, Table A-1, p. A-4.

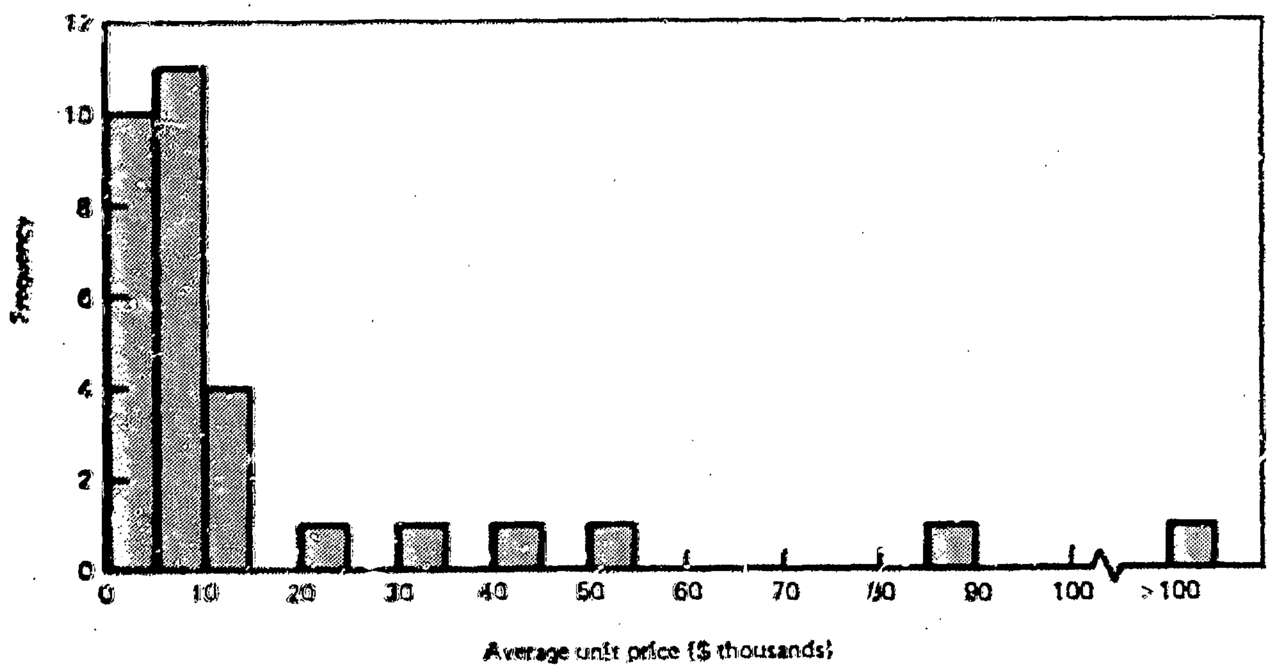

Fig. 2—Distribution of prices* in IDA79 sample

*Cumulative average price at end of sole-source production.
Source: IDA79, Table A-1, p. A-4

projected sole-source price." [p. 62] The IDA79 analysts used cumulative average prices to derive the sole-source progress or learning curve and adjusted to constant dollars, although they do not report the year to which the adjustment was made. The savings estimates were not discounted.

IDA79's attempt to develop a predictive model differed from the other three studies. The outcome variable IDA79 wished to predict is a measure referred to as "the competitive learning curve slope." This measure is actually the slope, on a log-log grid, of the line running from a point representing the cumulative average price at the end of sole-source production to a point representing the cumulative average price on the total procurement quantity. It seems misleading to refer to this line as a competitive learning curve: it reflects post-competition price behavior only in a very indirect fashion and its relationship to post-competition production costs is unknown.

IDA79's expectation was that the slope of this "competitive learning curve" could be predicted, on the basis of a linear regression, from the slope of the known sole-source learning curve. Sole-source slopes were, as already mentioned, derived from cumulative-average-price/quantity data points. IDA79 reported that when "just one aberrant item (the SPA-25)" was omitted from the regression, the outcome variable ("competitive learning curve slope") and the predictor variable (sole-source learning curve slope) were uncorrelated. [p. A-5] This left IDA79 having to use the mean of the measure referred to as "competitive slope" in the equation which is supposed to predict gross savings on competitive buys. The equation is the cumulative average variant of the standard learning curve equation: gross savings on competitive quantities are "predicted" as a function of the ratio of total quantity to sole-source quantity, known sole-source slope derived from cumulative average prices, and the mean (-.414) of "competitive slopes" from this 'sample' of 31 items.

IDA79 concluded--too optimistically in our view--that this "savings forecasting model is only a moderately successful predictor of actual savings." [p. A-7]

It is hard to tell whether IDA79 is actually recommending the model as a useful management tool. The model itself is presented in IDA79's

App. A and is used in App. C to estimate what the savings would have been had the Improved Hawk been competitively reprocured. It is, however, not even mentioned in App. F, where stylized examples are used "to illustrate the sensitivity to various assumptions of the estimated savings attributed to the introduction of competition." [p. F-1] Nor is it mentioned in the text of the report, which states:

> The reduction in unit cost is the most difficult component (of the internal rate of return) to forecast. It is in fact likely that no precise and stable predictive relationship exists; there are so many dimensions of variation surrounding each procurement (e.g., technology, market conditions) that each system is to a considerable extent unique.
>
> Experience with previous systems reveals considerable variation in the realized gross savings in unit prices after competition. (Findings on split-award and buy-out competitions are then summarized.)
>
> Based upon this information, reasonable, yet conservative figures for the projection of post competition savings are 10 percent for split-award buys and 20 percent for buy-outs. These numbers can, of course, be adjusted to incorporate information regarding the circumstances surrounding the procurement of a particular system. [pp. 83-84]

Although IDA79 makes much of the need to discount [Ch. VII and pp. 85-86], that is, to treat price-competitive reprocurement as an investment decision in which the time stream of costs and benefits is taken into account by computing a net present value or internal rate of return, the authors ignore the effects of discounting and the consequences of netting out in-house and external costs in their summary advice to decisionmakers quoted above. If program managers (1) project gross savings of 10 percent on split-buys and 20 percent on buy-outs, as IDA79 suggests, (2) take into account the costs of introducing competition, and (3) estimate the net present value or internal rate of return, they are most unlikely to come up with numbers suggesting that price-competitive reprocurement is a worthwhile investment.

WHAT CAN BE LEARNED FROM THESE FOUR STUDIES

These four studies contribute to our understanding of the competitive reprocurement process, but they do not (with the possible exception of electronic items) provide convincing evidence of savings due to competitive reprocurement, nor do they provide reliable quantitative tools for decisionmaking.

Credibility Problems Associated with Savings Estimates

If a decisionmaker is aware of the problems that may arise in transferring a complex production technology, of the additional administrative costs that will be incurred in setting up and managing a competitive production environment, and of the significance of discounting, he is likely to decide that competitive reprocurement is a risky investment indeed. And the doubts acquisition decisionmakers harbor about the dollar benefits derivable from competitive reprocurement are likely to be increased rather than decreased by a careful perusal of the existing quantitative research.

Savings estimates made by different analysts on a single system often vary enormously. Table 8 illustrates this phenomenon in the case of the Shillelagh missile. Different savings estimates calculated on the Shillelagh run all the way from 79 percent to -14 percent. Some of the reasons for this extreme variability on the Shillelagh and on other systems are (1) some analysts have calculated savings on the first competitive buy while others have estimated savings across all post-competition production; (2) where adjustments for sole-source learning have been made, different methods have been used to estimate the sole-source curve; and (3) some analysts have netted out some costs while others report gross savings. Half the estimates in Table 8 (those from p. 58 in IDA79) were in fact calculated by IDA79 to show the sensitivity of savings estimates to (2) and (3). If these five estimates that are a result of IDA79's sensitivity analysis are omitted, results still range from 79 percent to -8 percent.

Some of the variation in results shown on Table 8 stem from different definitions of savings, but differences in basic data interpretation also exist. The result is that a program manager looking for evidence of savings in previous programs can find a bewildering variety of answers, leading to serious data credibility problems and consequent disincentives to the use of competition.

Table 8

DIVERSITY OF SAVINGS ESTIMATES ON THE SHILLELAGH

Percent Savings Estimate	Source	Method
79	Yuspeh (1976), p. 111.	Lowest price [Martin's] on second split-buy compared with last sole-source price, in 1970 dollars. No adjustment for sole-source learning.
32	Carter (1974), p. 120	Sole-source learning curve projected from data in Yuspeh (1973), and savings computed as "the difference between the competitive bids of the developer and the second producer" [Martin], in 1970 dollars.
22	IDA79, p. 58(a)	Savings on competitive buy-out, recurring costs only, presumably in 1972 dollars. Sole-source learning curve exponent of -0.233 reported in APRO78 used to project sole-source price.
6	APRO68, p. 33	Savings on all post-competition production minus $746,000 in technology transfer costs as a percentage of total procurement costs, in 1972 dollars. Sole-source learning curve exponent of -0.233 derived from cost data for first two sole-source buys.
9	IDA79, p. 58(a) APRO78, p. 68	Savings on all post-competition production, recurring costs only, in 1972 dollars. Sole-source learning curve exponent of -0.233 from APRO78.
0	IDA74, p. 56	Savings on first competitive split-buy, in 1970 dollars. Sole-source learning curve exponent of -0.395 derived from price data.
-1	IDA79, p. 58(a)	Savings on first competitive split-buy, presumably in 1972 dollars, using the APRO78 exponent of -0.233 for the sole-source learning curve.
-4	IDA79, p. 58(a)	Savings on all post-competition production, recurring costs only, using a learning curve exponent (value not given) derived by IDA79 from APRO78 data. Presumably 1972 dollars.
-8	IDA79, p. A-4	Savings on all post-competition production, recurring costs only, using cumulative average price learning curve exponent estimated at -0.390. Constant dollars, year not given.
-14	IDA79, p. 58(a)	Savings on first competitive split-buy using learning curve exponent (the value is not given) derived by IDA79 from APRO78 data. Presumably 1972 dollars.

(a) These estimates were calculated by IDA79 to demonstrate the sensitivity of savings estimates "to different methods of estimating progress curves and to the inclusion of different costs." IDA79 also calculated other estimates on the Shillelagh not included here and equivalent series of estimates for all the other systems in the APRO78 study. See IDA79, pp 37-58.

Another indication of these credibility problems is the lack of ordinal agreement among studies analyzing the same subsets of items. As Table 9 indicates, there is disagreement in the rank-orderings by percentage gross savings (on all post-competition production) reported by APRO78 and IDA79 on the subset of items analyzed by both studies. This lack of even ordinal agreement between the findings from two studies using the same basic data is at least as worrisome as the disagreement among studies on a single system. The major stated difference between APRO78's method of estimating gross savings and IDA79's lies in the derivation of sole-source learning curves: APRO78 used unit production costs, whereas IDA79 used cumulative average prices. Savings estimates are, as IDA79 pointed out [pp. 57-79], very sensitive to the method of deriving the sole-source learning curve; it appears that even rank-orderings of savings are quite radically affected.

Taking into Account the Time Value of Money

The decision to reprocure competitively should be, as IDA79 argues, looked upon as an investment decision: costs are incurred in the present with the expectation of obtaining savings in the future. Because the

Table 9

RANK ORDERING BY POST-COMPETITION GROSS SAVINGS REPORTED BY APRO78 AND IDA79 ON ITEMS INCLUDED IN BOTH SAMPLES

Item	APRO78 Rank within Subset	IDA79 Rank within Subset	APRO78 Gross Savings ($ thousands)	IDA79 Gross Savings ($ thousands)
PRC-77 Radio	1	3	41.9	26.5
TOW Launcher	2	1	34.7	44.2
Bullpup AGM-12B Missile	3	2	26.9	31.7
TOW Missile	4	4	12.4	8.9
Shillelagh Missile	5	8	9.4	- 8.0
Sidewinder AIM-9D/G GCG	6	7	.7	- 4.6
Standard Missile	7	6	- 5.4	- 4.2
Sidewinder AIM-9B GCG	8	5	- 5.5	1.6
Mark 46 Torpedo	9	9	-29.4	-23.0

savings will begin to accrue several years after the initial investment in competition is made, it is important to take into account the opportunity cost of Government funds. Savings realized from competitive reprocurement will, when discounted at even the 10 percent rate suggested by OMB (let alone at the higher rates that would reflect the perceived scarcity of front-end funds), look much less impressive than undiscounted savings.

Among the studies we are familiar with, IDA79 is the only one to have examined the effects of discounting and then for only two systems: the Sparrow AIM-7F Guidance and Control System and the TOW Missile. The only obvious omission from IDA79's estimates are the additional in-house costs of introducing competition.[13] An internal rate of return of 12 percent, computed from data collected by IDA79, is reported on the Sparrow AIM-7F Guidance and Control System [p. B-9], a system that was competed for non-price reasons. On the TOW Missile, IDA79 reported an estimated internal rate of return of 24.2 percent, computed from data collected by APRO78. Using the 10 percent discount rate recommended by OMB, the net present value calculated by IDA79 for the TOW Missile was $19 million in 1972 dollars. [pp. 75-76]

By considering the APRO78 results on gross savings, we can get a rough idea of the effect of discounting when a portfolio of relatively complex systems, especially missiles, is being reprocured. The mean of gross savings on all post-competition production for APRO78's 'sample' of 16 items, mainly Army and Navy missiles, was 13.7 percent. Thus if the in-house and external costs of introducing competition were taken into account and if costs and savings were duly discounted, the net present value of investments in competition for this portfolio of systems would be negative--a fairly sizable loss, in fact. Whether this loss should be attributed to competition or to badly designed and

[13] The Sparrow estimate does take into account the costs of a contract with the Naval Weapons Center at China Lake. While these costs are technically in-house costs, and are so listed by IDA79, they covered the preparation of a TDP and technical support to the second source. Thus they are associated with the technology transfer process that would normally be external, rather than with the additional administrative load placed on Program Offices managing competitive environments.

implemented acquisition strategies (for instance, the failure of a program to prep^re well in advance for the introduction of competiton in the production phase) remains an open question at this stage of our analysis.

Predicting Price Reductions

Only two of the four studies--APRO78 and IDA79--claimed to have some success in developing a model that decisionmakers could use to predict price reductions attainable from competitive reprocurement. APRO78 offered as a predictive model an equation in which the outcome variable is the logarithm of the price after buy-out competition, the predictor variables are the logarithms of the expected sole-source price, and the ratio of the post-competitive-buy-out quantity to the total quantity. The choice of average post-competition unit-price as the variable to be predicted was not, unfortunately, a wise choice. A better choice would have been the difference between the expected sole-source price(s), itself a prediction, and price(s) under competitive conditions. To go after post-competition price directly, as APRO78 did, means that expected sole-source price is used as a predictor variable. The correlation between expected sole-source price and actual post-competition price is so high (.979 between the logarithms of the two prices in the APRO78 study)[14] that it swamps the effect of other variables.

The APRO78 authors stated that their model should be tested "on a system meeting (certain qualitative criteria) to verify its applicability and accuracy" before being adopted by the Comptroller of the Army as "approved procedure for independently (i.e., independent of the program manager) forecasting savings expected from competition." [p. 96] Testing the model on only one additional system, as APRO78 recommended, would not even come close to validating it.[15]

[14] APRO78 actually reports the correlation as being 1.00. [p. 70] Our recalculation was 0.979.

[15] See Mosteller and Wallace (1964) for a good case study of how to validate models on additional data.

The IDA79 approach was interesting and worth exploring but, given the lack of correlation between the sole-source slope and the "competitive learning curve slope," it turned out to be a blind alley. IDA79's fallback position, using the mean of the measure referred to as the "competitive learning curve slope" to predict gross savings, has all the weaknesses of any attempt to predict from a mean. In addition, the way the "competitive learning curve slope" is defined reflects the one-time effects of competition more than it reflects learning in the post-competition phase. IDA74 estimates of post-competition learning curves from post-competition price behavior show them to have shallow slopes, whereas the mean of the measures IDA79 refers to as "competitive learning curve slopes" is very steep--75 percent.

IDA79's predictive model is, as previously mentioned, a variant of the standard learning-curve equation. It is not a result of IDA79's regression analysis. It is, therefore, misleading when the authors, in discussing the implications of the equation, state: "As one would intuitively expect, the greater the quantity competed, the greater the expected percent savings." [p. A-5] The effect of the quantity ratio in IDA79's equation is determined solely by the assumptions of learning-curve theory: the quantity ratio in this equation must behave exactly as those assumptions say it should behave, i.e., with utter disregard for the data. IDA79's equation sets the exponent of the "competitive learning curve" equal to -.414, a slope of 75 percent, for all time. That is a rapid rate of learning. Few sole-source slopes will be that steep, so it is little wonder that the greater the quantity assumed to be produced under a 75 percent curve, the greater the gross savings.

These two studies (APRO78 and IDA79) which claim to have achieved some success in developing a model to predict price reductions from competitive reprocurement, placed heavy reliance on production-cost learning curve theory. They accepted the conventional wisdom, as do the Defense Acquisition Regulations (DARs), that the greater the post-competition quantity relative to the sole-source quantity the greater the price reductions from competition. Yet the multiple regression results reported by the two earlier studies, ECOM72 and IDA74, show the reverse: the greater the post-competition quantity relative to the sole-source quantity, the smaller the unit-price reductions on the first competitive buy. ECOM72 and IDA74 results also indicate that the effect of the quantity ratio is minor, i.e., the coefficient of the quantity ratio in the regression equations is (relatively) small. The IDA79 results provide no empirical information about the effect of the quantity ratio. The APRO78 results do: they are consistent with the ECOM72 and IDA74 results in showing a small coefficient for the quantity ratio and inconsistent in showing a positive correlation between the ratio of post-competition to sole-source quantities and unit-price reduction.

This one positive correlation seems to suggest that production-cost learning curve theory is not wholly irrelevant when it comes to predicting price reductions, but all the other findings indicate that it has not been helpful in explaining the results of competitive reprocurement. It may even have been a hindrance. IDA74 sounded a warning about production-cost learning curve theory. The authors pointed out that learning curve theory leads one to expect that the original vendor, the sole-source producer, should be able to win a competitive production contract easily because of the learning that has occurred during the initial period of sole-source production. This is not what happened, however, in the reprocurements examined by IDA74. When an item was reprocured competitively, the winning bidder in a majority of cases was not the original vendor. We were able to replicate this finding from IDA74 using the APRO78 data.

Learning effects presumably need to be taken into account in any model of competitive reprocurement, but how that should be done remains an open question. And a more important question is: What other variables should be taken into account in order to predict the price reductions to be expected from competition?

Current understanding of the competitive reprocurement process is meager. It would, for example, be an understatement to say that the determinants of post-competition price differences have not yet been identified. We were unable to discover a relatively complete list of even the potential determinants.

From these four studies, we do have some quantitative information on several proposed determinants: the ratio of post-competition to pre-competition quantities, lead-time ratios, delivery-schedule ratios, the exponent of the sole-source learning curve, split-buys versus buy-outs, and the number of bidders. There is some additional quantitative information on these and one or two other variables in other studies we are familiar with.[16] Some studies also provide, between the lines as it were, more qualitative information on several other potential predictor variables: complexity of the item, technological innovation (both rate and type) in the relevant industry, opportunities to market similar systems in the private sector, management of the technology transfer process, type of sole-source contract, etc.

Price differences (they are not always reductions) following the introduction of competition appear to be determined by many factors interacting in a complex fashion. To develop a model that can explain and predict these differences may require a thorough search through a varied literature: work on technology transfer, technological innovation, defense industry cost management and pricing strategies, etc. We have not undertaken this search, nor have we attempted any secondary statistical analyses of the data assembled by ECOM, APRO and IDA.[17]

SUMMARY

The existing body of analysis has not provided an adequate set of management tools for estimating either the benefits or the costs of competitive reprocurement. Furthermore, it indicates that much of the

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[16] See, for instance, Brannon (1980); IDA's Electronics-X by Gates et al. (1974); Neate and Burgess (1976); and Solinsky (1980). Due to various proprietary and political concerns, some, possibly many, studies that have been conducted for Program Offices, for OMB, for defense contractors, etc. are inaccessible. Perhaps if such studies were more generally available, more progress could be made in understanding competitive reprocurement quantitatively.

[17] If these data are to be re-worked, they should be completely re-worked. This would involve collecting additional information; at the minimum, additional information is needed to clear up the many inconsistencies between the information reported on a particular program by different studies.

conventional wisdom about competitive reprocurement rests on shaky foundations, and that we may know less about competitive reprocurement than we thought we did. However, some conclusions seem warranted:

- Savings on electronic items reprocured competitively by the Army have been substantial, but we do not yet know to what extent these savings are dependent on (a) technological innovations in the electronics industry confined to a particular time period, (b) ECOM's or the Army's effective management of electronics acquisitions, (c) the relative ease of tranferring the necessary technology from one electronics firm to another, (d) the existence of a commercial market for similar items which motivates producers to invest their own funds to ensure that the technology transfer process is successful, or any of several other explanations.[18]
- One of the major decisions in a competitive reprocurement is when in the production run to introduce the second source. If it is done too early, there is an inadequate experience base with the sole source; his costs are not well established, and the design itself may still be undergoing some evolution. If the second source is introduced too late, on the other hand, opportunities for savings may have been forgone. The DAR may not be promulgating the most economically beneficial advice in suggesting that quantities procured under an initial sole-source production contract be kept to a minimum so that competitive reprocurement can be introduced as early as practicable. Minimizing sole-source quantities and maximizing post-competition quantities does not appear to generate the largest post-competition price reductions. Without verifying and re-analyzing the existing data, however, we cannot say what should be done instead. And we cannot even be sure that a re-analysis of existing data would tell us, within any acceptable

[18] See Gates et al. (1974), Electronics-X, for a discussion of some of these issues.

confidence intervals, what we would need to know. It may be necessary to collect data on additional instances of competitive reprocurement to understand the relationship between quantity ratios and price reductions.

- While production costs tend to decrease with increasing quantities produced, suggesting that the original producer should be able to win a competitive award hands down, we find that the original producer often loses when an item is reprocured competitively. But we do not know why. IDA74 presents some convincing evidence suggesting that ASPR profit weights for sole-source contracts will motivate a profit-maximizing producer to set up a production process that is inefficient. Then when this producer faces competition from a second source, he seems unable to shift to a more efficient production process.
- It is not clear whether competitive reprocurement pays off as a financial investment on systems as complex as missiles, because there is as yet no evidence that internal rates of return are high enough to justify the drain on front-end funds.
- More might be learned from a re-analysis of the data already assembled, assuming that at least the major inconsistencies and omissions in these data could be rectified; it is not possible at this point to estimate how much more, because data problems are severe. Data on competitive reprocurements are difficult to retrieve; and adequate, complete, and consistent data are almost non-existent, according to those who have assembled the current data base. If data collection, storage, and retrieval systems remain as they are, our quantitative understanding of the competitive reprocurement process is likely to remain weak into the 1990s.

IV. CONCLUSIONS AND RECOMMENDATIONS

As a system moves through the acquisition cycle, the application of competition changes in two major ways: the benefits sought from competition change, as does the perceived ratio of costs incurred to benefits obtained. Thus an analysis of the role of competition in weapon system acquisition must examine individually at least three distinct acquisition phases. Prior to the beginning of full-scale development, the benefits sought from competition are a complex blend of desires to improve the design concept, reduce performance and schedule risks, and minimize cost. In this phase the dollar investments needed to establish and maintain competition are rather small, although additional management burdens are imposed on the Program Office. Conversely, the benefits of competition are widely perceived as being valuable. This perception appears to be rooted in "conventional wisdom" rather than the results of any quantitative comparisons, and in fact quantitative analysis is virtually impossible due to the multiple objectives and the difficulties of comparing outcomes in competitive and non-competitive programs. However, the perception of benefits is widely and strongly held, and competition is the norm under these circumstances.

As the design moves into full-scale hardware development, the choices of design concept are narrowed (usually to a single design) and the anticipated benefits of competition shift toward reduction of risks and costs. In this phase, however, the cost of maintaining multiple sources rapidly escalates and the belief in equivalent benefits dwindles. Again the perception of benefits is highly subjective, with virtually no basis in quantitative comparisons between sole-source and competitive development programs. Competition is rare at this stage of weapon system acquisition.

Competition in the production phase is usually viewed as a means of reducing cost to the buyer (although other benefits are possible and sometimes sought). As in the full-scale development phase, the investment needed to introduce competition is frequently sizable. However, in this phase we encounter for the first time an opportunity to collect quantitative evidence on the benefits of introducing competition. A price pattern established by an initial, sole-source production program can be compared with actual bid prices when competitive sources are brought into the program. Unfortunately, due to inadequacies in both theory and data, such comparisons have not yet produced a methodology enabling a program manager to confidently predict post-competition prices and thus potential savings. On the other hand, at least some of the costs of qualifying a second source (transfer of technology, production and test of initial qualification quantities, etc.) are quite apparent, and the manager finds in the DARs and the policy directives only narrow justifications for competition. The combined result is that the introduction of competition into an ongoing production program appears risky to a program manager. Thus it is not the common practice, especially in the more complex "major" system acquisition programs. The diversity of costs, desired b[illegible]fts, and levels of perceived uncertainty regarding the introduction of c[illegible]ition during these three phases of acquisition illustrate the difficulty of changing the amount and utility of competition.

Although considerable research on competition has been performed, reliable guidelines for acquisition managers have not yet been developed. Existing research provides neither quantitative nor qualitative guidance for designing price-competitive reprocurement strategies--one of the simplest, and certainly the most quantifiable, uses of competition. Methodologies should be developed to forecast and evaluate the costs and benefits of various competitive strategies--not just the effect on price of competition in the reprocurement phase. Lacking such methodologies, program personnel are unable effectively to justify competition expenditures and DoD is unable to develop criteria for selective application of competition. Further, without knowing how to evaluate competition in the context of acquisition, decisionmakers will tend to focus on the degree to which competition is or is not applied, instead of how much it has or has not increased the effectiveness of systems acquisition. The development of such methodologies, however, will be neither simple nor rapid, given the difficulties of retrieving adequate information about past programs.

One simple but valuable step would be to ensure that adequate records are retained on current competitive acquisition actions so that future analysis can benefit from an adequate data base. Such a data base, and the subsequent analysis, should focus on a broad set of characteristics of individual weapon systems as determinants of contract outcomes, as opposed to only learning curves and cost relationships. The following are examples of the kinds of information that would be useful to the analyst but that are not now collected in any systematic way:

- The degree of technological sophistication involved in the system, and the technical advance it represents over the previous-generation system.
- The program environment, in terms of the various risks perceived, the urgency of development, the number of competing firms involved and their relative capabilities.
- The business approach used (the organization of the Service and contractor management teams, types of contracts used).
- The expected size of the production run, both formally stated and informally expected by the participants.
- The business posture of the competing firms (business base, availability of key personnel to work on the subject project, existence of special facilities or other elements that might give it a competitive edge, etc.).
- The extent and type of competition that existed before the beginning of FSD, or the beginning of production.
- The quality of the resulting product, and the reasons for any quality or other major shortfalls.

The role of the contract should also be considered in more detail. Even when contracts are classified as being of the same type, many aspects may vary widely, such as escalation clauses, penalties, award fees, payment ceilings, and so forth.

Finally, the underlying theory of how competion should function in weapon system acquisition appears to be inadequately developed.

Numerous important questions have not been adequately examined, including:

- In what circumstances does competition lead to cost reductions in production, or profit reductions, or some combination of the two?
- Does competition influence a firm's efficiency by inducing it to invest in capital equipment, manufacturing technology, or product development? Under what circumstances?
- How does the firm's general business situation and alternative investment strategies affect the impact of competition?

Research on the development and refinement of such elements of a theory would be extremely valuable if it could provide a solid framework to guide the collection of data and the design of future data analysis.

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This report examines methods for improving the effectiveness of competition in the acquisition of major weapon systems. Use of competition at the concept design stage is known to be inexpensive relative to benefits. However, competition is rare during procurement when the expense is immediate and any savings are delayed. Existing analysis provides no means for evaluating competitive reprocurement. Savings on competitively reprocured electronic items have been substantial but the factors explaining this are unknown. The best point in production at which to introduce a second source cannot now be determined. Also unclear is whether competitive reprocurement pays off for complex systems. Because price-competitive reprocurement strategies are one of the simplest and most quantifiable uses of competition, this study recommends improved data collection on current competitive acquisition, and further theoretical study of the function of competition in such acquisition.