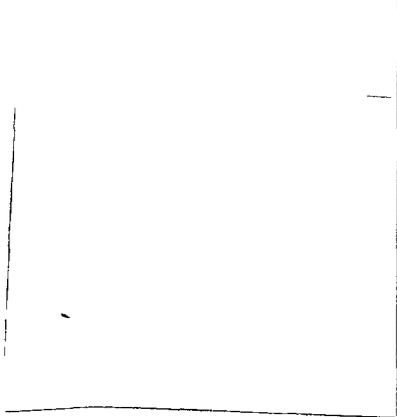


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REPORT TO THE CONGRESS



Theory And Practice Of Cost Estimating For Major Acquisitions

B-163058

Department of Defense

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

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JULY 24, 1972



COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON D C 20548

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To the President of the Senate and the
Speaker of the House of Representatives

This is our report on the theory and practice of cost estimating for major acquisitions in the Department of Defense

Our review was made pursuant to the Budget and Accounting Act, 1921 (31 U S C 53), and the Accounting and Auditing Act of 1950 (31 U S C 67)

Copies of this report are being sent to the Director, Office of Management and Budget, the Secretary of Defense, and the Secretaries of the Army, Navy, and Air Force

James B. Stacks

Comptroller General
of the United States

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ABBREVIATIONS

DOD Department of Defense
GAO General Accounting Office
SAR Selected Acquisition Report
WBS work breakdown structure

D I G E S T

WHY THE REVIEW WAS MADE

Realistic cost estimating is indispensable to decisionmaking by both the Congress and the military services' management during the process of acquiring a new weapon system. Previous General Accounting Office (GAO) reports have shown that estimates of the cost to develop and produce a weapon system are frequently understated. Data available on 47 weapon systems show cost increases of \$15.6 billion from early development estimates. The Department of Defense attributed 43 percent of this amount, or \$6.7 billion, to estimating changes. GAO attempted to identify those factors in the cost-estimating function that were causing the problem and to offer suggestions as to how the problem might be solved or abated.

FINDINGS AND CONCLUSIONS

Uniform guidance on cost-estimating practices and procedures which would be the basis for formulating valid, consistent, and comparable estimates throughout the services was lacking. Each service issued its own guidance for the estimating function, which ranged from a detailed estimating manual to a few general statements. Guidance was often ignored by the estimators.

Cost estimates for a specific system frequently are a succession of revisions, the current cost estimate is derived by refining and revising the preceding cost estimate. Accurate revision of both the original and updated cost estimates requires documentation showing data sources, assumptions, methods, and decisions basic to the estimate. In virtually every system GAO reviewed, documentation supplying such information was inaccurate or was lacking. Among the resulting difficulties were:

- Known costs had been excluded without adequate or valid justification
- Historical cost data used as a basis for computing estimates were sometimes invalid, unreliable, or unrepresentative
- Inflation was not always included or uniformly treated when it was included
- Understanding and proper use of the estimates was hindered

Readily retrievable cost data which could serve as a base for computing cost estimates for new weapon systems generally were lacking. Officials

within the Office of the Secretary of Defense stated that there was little organized effort to gather actual cost information systematically, to achieve comparability between the data collected on various weapon systems, or to make any effort to see whether the cost data the contractors reported were accurate and consistent

Without realism and objectivity in the cost-estimating process, bias and overoptimism creep into estimates prepared by advocates of weapon systems and the estimates tend to be low. Therefore persons who are not influenced by the military organization's determination to field a weapon system, or by the contractor's desire to develop and produce the system, should review every weapon system at major decision points in the acquisition cycle

RECOMMENDATIONS OR SUGGESTIONS

The Secretary of Defense should develop and implement guidance for consistent and effective cost-estimating procedures and practices throughout the Department of Defense (DOD). In developing this guidance he should consider the criteria for cost estimating set out in this report. Of particular importance is provision for

- An adequate data base of readily retrievable cost data
- Treatment of inflation
- An effective independent review of cost estimates, including judgment by top officials as to the realism of the cost estimates on which decisions are based
- More complete documentation of cost estimates, coupled with a requirement for an adequate feedback of results, to provide a basis for comparing costs achieved with those estimated

AGENCY ACTIONS AND UNRESOLVED ISSUES

DOD stated that it agreed with GAO's conclusions. DOD plans

*** to provide the necessary guidance to the DOD components. This would include criteria to guide those charged with making estimates and would establish procedures to have cost estimates, which were prepared within this guidance, available for use by the Services and the Secretary of Defense. In addition, it would provide guidance necessary for the creation and maintenance of data systems for cost estimates."

GAO was advised that

"*** the Services have all taken steps to improve their cost estimating capability. For instance, the Department of the Navy has established a Resource Analysis Group ***. The Department of the Army is appointing a project manager who will be responsible for development of an independent *** estimate [based upon historical experience with prior similar systems] for each system covered by a SAR [Selected Acquisition Report] or subject to a DSARC [Defense Systems Acquisition Review Council] review ***. The Air Force Systems Command is about to reissue its Cost Estimating Manual *** which will include all the criteria for good cost estimates discussed in your [GAO's] report."

MATTERS FOR CONSIDERATION BY THE CONGRESS

This report provides the Congress with an independent evaluation of the practices and procedures associated with cost estimating for major acquisitions by DOD.

CHAPTER 1

INTRODUCTION

Realistic cost estimating is indispensable to both the Congress and agency management for selecting and evaluating a new weapon system and for cost control during the system's acquisition process. Valid estimates provide a reliable basis for deciding what systems are to be developed and whether a program should be continued, modified, or stopped.

The Department of Defense (DOD) has classified its total program cost estimates as (1) planning estimates, (2) development estimates, and (3) current estimates. These terms are used throughout this report.

The planning estimate is the total program estimate and is used by the Secretary of Defense in deciding whether to move the program from the conceptual phase to a more advanced validation phase. It is generally considered to be the initial program estimate for acquiring a weapon system.

The development estimate is a refinement of the planning estimate and is made during the period in which preliminary design and engineering are verified or accomplished and in which contract and system management are planned.

The current estimate is intended to be an up-to-date estimate of the cost of acquiring the total approved program. It is adjusted as changes occur in the program.

MAGNITUDE OF THE PROBLEM

For 47 weapon systems the cost growth from the development estimates to the current estimates totaled \$15.6 billion as of March 1971. Of this amount, about \$6.7 billion, or 43 percent, was classified in the "estimating changes" category, defined by DOD Instruction 7000.3 as.

"A change in program or project cost due to refinements of the base estimate. These include mathematical or other errors in estimating, revised estimating relationships, etc. Excluded from this

category should be revisions of cost estimates that occur because of other change categories, i.e., engineering, support, schedule, etc. For example, a cost change which occurs because of the addition of a new warhead is an engineering change and not an estimating change, a revised production schedule is a schedule change, not an estimating change "

A summary of program cost estimates for the 47 weapon systems reported on Selected Acquisition Reports (SARs) prepared by the military services is shown in the table below

Cost Estimates as of March 31, 1971

Service (number of systems)	<u>Planning estimate</u>	<u>Development estimate</u>	<u>Current estimate (3-31-71)</u>	<u>Cost changes between cols 4 and 3</u>	<u>Cost growth due to esti- mating changes</u>
	(millions)				
Army (10)	\$12,677 9	\$12,757 2	\$ 15,030 0	\$ 2,272 8	\$1,378 7 61%
Navy (24)	23,387 6	37,423 4	45,978 3	8,554 9	3,831 0 45
Air Force (13)	<u>36,080 6</u>	<u>43,646 7</u>	<u>48,424 8</u>	<u>4,778 1</u>	<u>1,446 0</u> 30
Total (47)	<u>\$72,146 1</u>	<u>\$93,827 3</u>	<u>\$109,433 1</u>	<u>\$15,605 8</u>	<u>\$6,655 7</u> 43

The \$37.3 billion difference between the planning estimate and the current estimate represents the total cost change from the cost initially forecast to the cost currently estimated through program completion. The SARs explain only that part of these total cost changes between the development estimate and the current estimate and classify these changes into nine categories intended to give insight into the underlying causes of the cost variances.

Figure I shows that cost attributed to estimating changes is a significant part (61 percent in the Army, 45 percent in the Navy, and 30 percent in the Air Force) of the total system cost growth from the development estimate to the current estimate. Cost growth data of the type reflected above is available on only 47 of the approximately 130 major systems in the DOD inventory.

EXTENT OF THIS REVIEW

It is clear that the underlying cost-estimating difficulties, as well as the problems of using these estimates for decisionmaking purposes, are complex. Therefore we reviewed estimates of 18 weapon systems presently in various stages of acquisition, to provide a basis for evaluating the cost-estimating process.

The weapon systems included in our review were

<u>Army</u> (7)	<u>Navy</u> (3)	<u>Air Force</u> (8)
BUSHMASTER	HARPOON	AWACS
DRAGON	LAMPS	A-X
Heavy-lift helicopter	MARK-48	B-1
MBT-70		F-15
SAFEGUARD		MINUTEMAN III
SAM-D		OTH-B
TOW		SRAM
		Program 777

PERCENTAGE OF COST GROWTH DUE TO ESTIMATING CHANGES FOR SELECTED WEAPON SYSTEMS AS OF MARCH 31, 1971

PERCENT OF COST GROWTH OF THE CURRENT
ESTIMATE OVER THE DEVELOPMENT ESTIMATE

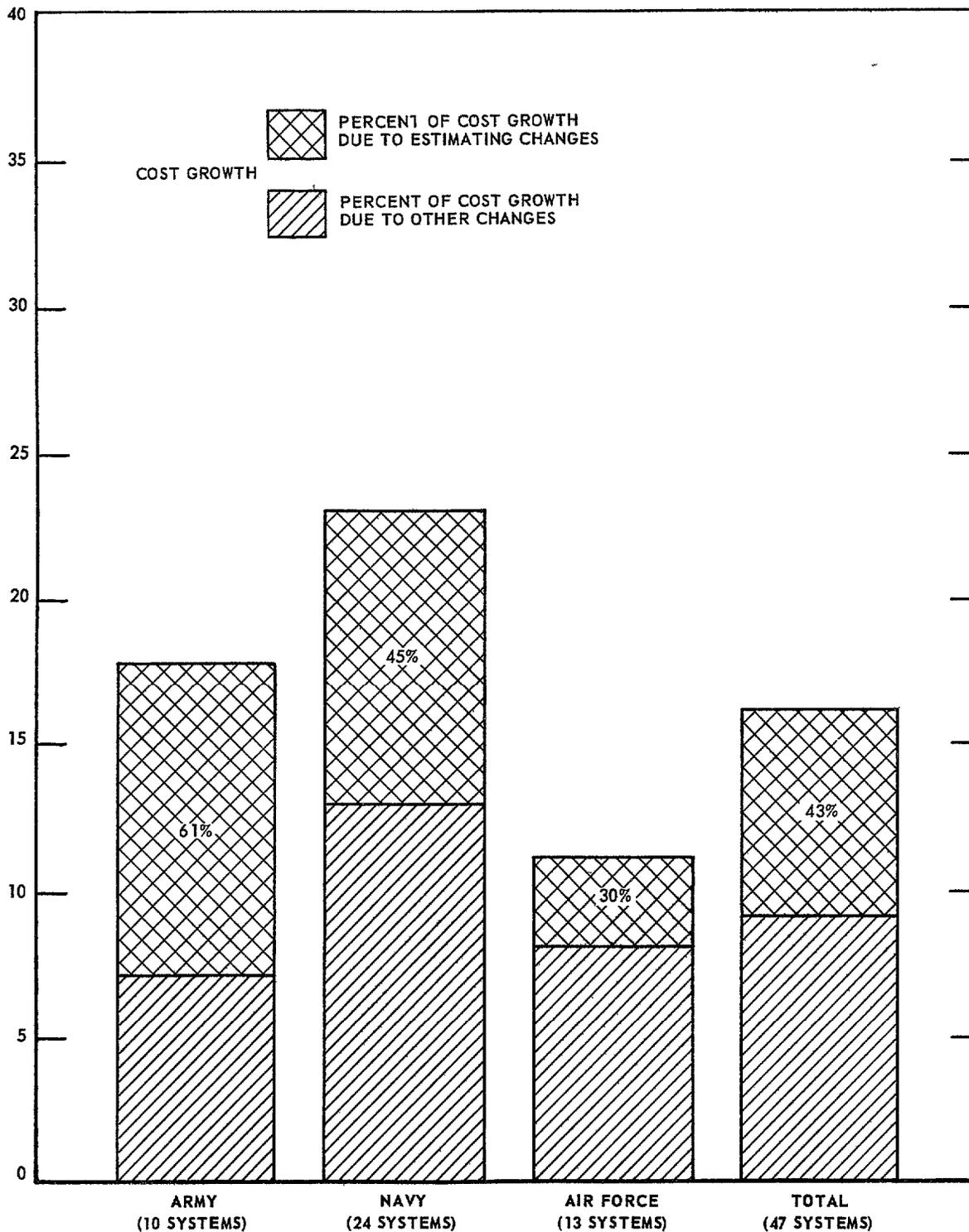


FIGURE 1

CHAPTER 2

EVALUATION OF COST-ESTIMATING PROCESS

We used various DOD documents and our own experience to develop criteria that we feel are basic to an effective estimating process. We evaluated individual major weapon systems' estimates against these criteria. Some examples of what we found on individual weapon systems are used to illustrate where the performance in meeting the criteria has been good and where it has been poor. These criteria concern the need for

1. Clear identification of task.
2. Broad participation in preparing estimates.
3. Availability of valid data.
4. Standardized structure for estimates.
5. Provision for program uncertainties (risks).
6. Recognition of inflation.
7. Recognition of excluded costs.
8. Independent review of estimates.
9. Revision of estimates when significant program changes occur.

A discussion of each of these criteria follows.

CLEAR IDENTIFICATION OF TASK

In preparing an estimate the initial step is to define the estimating task. To do this, the estimator must be provided with the system description, the ground rules and assumptions, and sufficient information for determining the purpose and scope of the estimate.

A well-defined description of the weapon system includes performance characteristics and specifications which form a basis for the cost estimate. An adequate system description can eliminate possible misunderstanding and can help insure that there are no omissions relative to performance, design, or other cost-related factors. Therefore sufficient data must be collected on all facets of the system which may impact on costs. Some facets which should be included are (1) mission, (2) configuration--types and quantities of equipment, personnel, and facilities, (3) performance characteristics--speed and range, (4) training concepts, (5) development, procurement, and test schedules, and (6) technology required. These elements should be carefully documented and updated as changes occur in the system.

A ground rule, provided by the requestor of the estimate, is a specified condition or constraint which the estimate must satisfy. Assumptions are made by the estimator in cases where the ground rules do not completely define all conditions necessary for the development of the estimate.

These ground rules and underlying assumptions should be determined prior to the preparation of the estimate and should be clearly identified in the supporting documentation. They should be defined to a level of detail which will aid the estimator in the preparation of a valid estimate and which will permit use of the estimate with confidence and full understanding of its contents.

The use that is to be made of the completed estimate will influence the estimating method to be used and the scope of the costs to be covered. It is essential that the purpose and scope of the estimate be clearly identified and documented in the narrative to preclude its misuse and to advise officials of its contents and how it was prepared.

Some examples of the adequate application of this criterion follow.

Adequate application of criterion

A-X close-air-support aircraft

An A-X aircraft cost estimate was based on the mission, configuration, and performance characteristics of the

proposed A-X aircraft and a proposed schedule for development, procurement, and testing of a specified quantity of aircraft. The number of flight-test hours and the rate of production were defined.

Information in the concept formulation package showed that no advancement in technology was required to develop and produce the proposed A-X aircraft. Additionally, the estimated cost of operating one wing of A-X aircraft for 10 years was included in the concept formulation package and the development concept paper. Items included were (1) modifications, maintenance support, and procurement of spares, (2) operation and maintenance, (3) personnel costs, and (4) related base-operating support.

SAFEGUARD

The purpose and scope of the May 1969 planning estimate for the two-site, phase 1 SAFEGUARD system was known to the estimators and was shown in documentation provided to all levels of management.

The estimate was developed by a working group of top-level managers from the SAFEGUARD System Office, SAFEGUARD System Command, and from other Government agencies and industry organizations directly involved with the system. The stated purpose and scope of the estimate was (1) to show the development, production, and construction costs of acquiring the system and (2) to describe the changes and costs associated with the change in deployment concepts--from SENTINEL to SAFEGUARD.

BROAD PARTICIPATION IN PREPARING ESTIMATES

Planning, directing, and controlling the definition, development, production, and operation of a weapon system involves numerous Government agencies and contractors. Those that will incur significant costs in support of the program should provide input to the cost estimates. Those immediately involved in the program, if they are objective, are in a better position than anyone else to estimate costs. Naturally these inputs should be subjected to independent verification and each agency and contractor activity should have controls to insure that the data supplied are complete and reliable.

The first example below illustrates how an estimate was prepared for a system early in the acquisition cycle. The second example illustrates how an estimate was prepared for a system in the production phase of the acquisition cycle.

Adequate application of criterion

HARPOON

The cost-estimating team, in preparing the cost estimate contained in the HARPOON Weapon System Validation Phase Report dated July 31, 1970, requested and received assistance and input from various Government operations and contractors which were expected to incur significant costs. For example, the supporting files contain various system or subsystem cost estimates from selected contractors, such as General Dynamics, McDonnell-Douglas, and North American Rockwell.

In addition, the Naval Weapons Center, China Lake, Calif., made studies and provided various data and subsystem cost estimates that the estimators used in arriving at the total system cost estimate. The Naval Air Systems Command logistics group provided logistics support data and estimated costs for logistics support.

We were advised that the data obtained from both in-house and contractor sources were independently verified by the cost study team.

MINUTEMAN III

The primary focal point within the MINUTEMAN III program office for developing cost estimates is a group of 40 project element officers. Each officer is responsible for managing a part of the program. When cost estimates for the MINUTEMAN III program are prepared, these project officers contact each contractor and Government agency expected to incur significant costs and request it to submit estimates for specific parts of the program.

Each project officer, in making recent program estimates for the MINUTEMAN, prepared a pricing instruction that described his part of the program by work objective. These instructions were issued to associate contractors who priced and/or repriced their individual parts of the program. The project officers also obtained estimates from contributing Government agencies, such as the Air Force Logistics Command, the Air Force Weapons Laboratory, and the Arnold Engineering Development Center. The project officers reviewed and analyzed the cost estimates received before incorporating them into the summary program estimate. Sometimes independent cost estimates were prepared by a MINUTEMAN cost-analysis group to validate the cost estimates received from other organizations.

AVAILABILITY OF VALID DATA

The cost estimator has numerous sources of data available when estimating the cost of a weapon system. Some obviously are more reliable than others. A principal source of data is an historical base; i.e., the costs experienced on similar or comparable systems or components are used as a basis for estimating the cost of new systems. The estimator, before using these data, should be assured that they are suitable for the purposes intended. The data should reflect current costs, should be directly related to the system's performance characteristics and specifications, and should be unbiased so as to present an objective appraisal of anticipated costs.

Office of the Secretary of Defense officials stated, in a report dated September 5, 1970, concerning cost-estimating techniques, that there was very little organized effort to

gather actual cost data systematically, to achieve comparability between the data collected on various weapon systems, or to see if the cost data being reported by the contractors were accurate and consistent. These officials also stated that, although most commands had data libraries, they had little readily retrievable data and that there was an indication that much of the estimators' time was taken up by a quest for data rather than by the estimating function.

Following are examples of where the criterion for valid and reliable data sources was adequately applied and where it was not

Adequate application of criterion

B-1 aircraft

The Aeronautical Systems Division data bank was the primary source of data for developing the computer cost model used in preparing Air Force estimates for the B-1 aircraft. The data were obtained from system program offices and contractors within the limits of the cost-reporting systems of current aircraft, including the F-111, F-15, A-7, C-5A, and the A-5. Historical data on other aircraft, obtained from contractors' records, Aeronautical Systems Division cost studies, and research organizations, were used when considered appropriate.

The F-111 aircraft data were used extensively because the F-111's performance characteristics were considered to be most like those of the B-1 aircraft. The data and the cost-estimating relationship source used in the model were cited in the narrative of the methodology for each item in the work breakdown structure.

HARPOON

In preparing the research and development part of the HARPOON's life-cycle cost estimate, the cost study team collected and analyzed estimated and actual development costs of the PHOENIX, CONDOR, and STANDARD missile systems and various contractors' planning estimates for their specific approaches to the HARPOON missile. In addition, the cost team collected and analyzed responses from functional groups

in the Naval Ship Systems Command and Navy laboratories relative to the comparative technical complexities of the HARPOON missile system and those of the PHOENIX, CONDOR, and STANDARD missile systems. This comparison was then used as the basis for determining the range of probable costs associated with the development of the HARPOON missile subsystem. Similar data sources were used in estimating the production cost of the HARPOON system.

Inadequate application of criterion

SAFEGUARD

The June 30, 1970, program estimate for the SAFEGUARD did not use the latest data available for the construction segment of the estimate. The construction costs were based on an April 1969 computation by the Corps of Engineers. No use was made of the more current data available from a March 1970 contract award under the SAFEGUARD program for construction of facilities at Grand Forks Air Force Base. The use of the outdated cost data resulted in an understatement of \$11 4 million for construction costs at that location.

Corps officials told us that the June 30, 1970, construction estimate had not been adjusted to reflect the awarded contract because the Division Engineer decided that differences between the contract price and the original construction estimate had not been sufficiently defined and assessed for justifying an increase to the SAFEGUARD System Manager.

STANDARDIZED STRUCTURE FOR ESTIMATES

DOD provides a standard method, called the work breakdown structure (WBS), for dividing the total acquisition task into specific work packages. The identification of these work packages becomes more detailed as the weapon system progresses through the acquisition cycle. To insure that estimates can be related in a meaningful way to the total program, WBS should be used for structuring program cost estimates.

WBS provides a systematic approach which helps preclude the inadvertent omission of costs. In addition, it serves

as a vehicle for the constant refinement of cost estimates as the program progresses. An estimate derived from WBS also assists management in monitoring, controlling, and coordinating the various project activities being conducted by the service and by contractors.

Following are some specific examples of adequate and inadequate application of the criterion.

Adequate application of criterion

AWACS

The initial estimate for AWACS, prepared in October 1967, employed a summary WBS for preparing estimates for major subsystems and related support categories. As the system progressed through the acquisition cycle and as requirements were definitized, WBS was refined and expanded. By the time of the development estimate in June 1970, WBS had been defined at the lower levels for effective management of the total task.

Inadequate application of criterion

LAMPS

The LAMPS cost estimate contained in a draft technical development plan prepared by the Naval Air Systems Command in September 1970 was derived from a summary WBS, but the summary WBS was not used to insure that the cost estimate included all major elements of the system. The costs of two major elements--ship-related support equipment and spare parts--were omitted from the estimate

DRAGON

The June 1970 DRAGON program acquisition estimate was divided into two parts. development and procurement. The procurement segment was shown at the WBS level, but the development portion was not. Because the development estimate was not documented in WBS detail, there was no checklist to insure that all relevant items had been included.

PROVISION FOR PROGRAM UNCERTAINTIES (RISKS)

One of the most important and difficult aspects of cost estimating concerns identifying uncertainties and developing a realistic allowance for their cost impact. Work objectives should be divided into knowns and unknowns. Provision should be made for the cost of resolving these knowns and unknowns.

Engineering-risk analyses and technical feasibility studies should be made to identify technical uncertainties. Special provisions should be made for high-risk areas in the development of the system, and these areas should be reflected in the cost estimate.

Historical data for similar systems or for systems of similar complexity should be taken into account, because such data may indicate the extent to which studies did not identify risks and therefore may provide a basis for cost estimating.

Documentation which fully reveals the risks, their cost impact, and the rationale used to determine the impact should be an integral part of the cost estimate.

Following are some examples of adequate and inadequate application of this criterion.

Adequate application of criterion

SAM-D

The U.S. Army Missile Command, in preparing the SAM-D system life-cycle cost estimate in 1970, provided for technical uncertainties in the program and, for the first time, allowed for their cost impact.

Work objectives were segregated into knowns and unknowns. A technical-risk analysis was performed by the missile command to identify potential development areas, quantify the degree of associated risk, assess the relative importance of the problem, and recommend development and test program adjustments where appropriate. The prime contractor's efforts were investigated in detail to identify risks and to assess the steps taken to accommodate these risks.

High-risk items were analyzed to determine what program changes were needed to secure a high probability of success for the items.

BUSHMASTER

The BUSHMASTER's development concept paper indicated that this weapon system was within the state of the art. Engineering-risk analyses were prepared to identify risk areas, and the documentation included a description of the rationale and method used to estimate the cost of uncertainties. The technical risk section of the current estimate, dated June 1970, showed that all risks were in the medium- to low-risk category.

The rationale used for dealing with the identified-risk areas and the potential effect of risks were fully discussed. The estimate presented the possible program delay and additional costs anticipated if failure were experienced in any risk area and an alternative solution were required.

Inadequate application of criterion

SRAM

We were informed that engineering-risk analyses were not used for the SRAM estimates. Recent estimates prepared by the System Project Office were based on contract amounts and contractor cost estimates and did not make use of engineering studies. The independent cost-estimating teams also did not directly use engineering studies in preparing their estimates. None of nine SRAM estimates prepared by the System Project Office, Headquarters, U.S. Air Force, and the independent cost-estimating teams that we reviewed in detail identified any risk area.

RECOGNITION OF INFLATION

Changes in the Nation's economy over the span of a system's acquisition can significantly impact on the cost to develop, produce, and operate a weapon system. Perhaps there is little that DOD can do to control the effects of inflation. Nevertheless inflation is a real factor that has contributed to cost growth in the past and it is important that it be

recognized if valid cost estimates for the total program are to be prepared. Providing for inflation will result in more realistic estimates, consequently changes in estimates which may be attributed to inflation will be reduced.

To help achieve comparability between estimates and to preclude any misunderstanding of how inflation was treated, the estimator should document a detailed description of the method used. Comparability would also be facilitated by consistent treatment of inflation.

Following is an example of inadequate application of this criterion insofar as making some provisions for the impact of inflation is concerned.

Inadequate application of criterion

LAMPS

The LAMPS cost estimate for the September 1970 technical development plan was inconsistent in its treatment of inflationary allowances. The narrative pertaining to the cost estimate stated that production costs included an annual inflation rate, but certain portions of the cost estimate did not include this inflation rate. For example, the ship electronics part of the estimate did not contain any provision for inflation. A Navy representative responsible for preparing that part of the estimate informed us that a provision for inflation had been omitted because he believed that the requirements would change. We were also informed that the estimated cost of the interface part of the ship segment estimate included an allowance for inflation, but no specific rate was shown.

The narrative explanation of the estimate stated that future rates of inflation were somewhat unpredictable and that therefore an inflationary rate was assumed. The estimating files that we reviewed did not document the basis for the assumed rate. We were informed that the assumption regarding anticipated inflation had been predicated on the cost estimator's analysis of economic trends. This analysis also was not documented.

The omission of an inflationary allowance understated the estimated cost of acquiring LAMPS.

RECOGNITION OF EXCLUDED COSTS

Weapon system cost estimates are normally expected to contain provisions for all costs expected to be associated with that system. If major costs have been excluded from an estimate, it is important that the estimator disclose that information and fully explain the reason for excluding the costs so that just exactly what elements are contained in the estimate can be understood by all users.

An example of the inadequate application of this criterion follows.

Inadequate application of criterion

CONUS OTH-B

The CONUS OTH-B radars are planned to be part of the North American Air Defense Command's warning system and will require additional equipment to interface. The December 1970 estimate did not include provisions for, or explanations of, the additional equipment and did not explain the reasons for excluding the estimated costs of this equipment.

INDEPENDENT REVIEW OF ESTIMATES

A well-founded, properly documented cost estimate relies on the effective functioning of the cost-estimating process at every level within the total management structure. An independent review of the estimate is an integral part of this process.

The independent reviewer must objectively examine the work of the original estimator and verify, modify, or amplify it as necessary, to insure completeness, consistency, and realism of the information contained in the cost estimate. The reviewer should fully explain his findings so that the benefit of his assessment is available to all users of the estimate.

There should be both procedural and organizational accommodations for handling proposed changes. Any changes made to estimates during the review process should be coordinated with the original estimator and with other interested parties, to insure the validity of the change and to maintain continuity in the estimating process.

Following are examples of inadequate application of the criterion

Inadequate application of criterion

BUSHMASTER

The planning estimate for the BUSHMASTER was not subjected to an independent formal review process at any level of the management structure prior to its inclusion in the development concept paper. The source data used for the planning estimate required a significant amount of revision and updating to reflect current-year (1969) dollars and reduced requirements. The estimate contained cost omissions, inconsistencies in the application of cost data, and mathematical errors which should have been noted if an independent review had been performed.

HARPOON

The estimate contained in the HARPOON Weapon System Validation Phase Report dated July 31, 1970, was not subjected to an independent in-depth review. The only review of the estimate was made by the cost team leader who was responsible for its preparation.

REVISION OF ESTIMATES WHEN SIGNIFICANT PROGRAM CHANGES OCCUR

The process of acquiring a major weapon system is a long, difficult task usually marked by many changes along the way. Initial cost estimates for an acquisition are frequently formulated with limited technical knowledge of the system to be developed and are at best educated guesses. As the system progresses through the development cycle, however, more definitive information becomes available on the requirements of the system and more accurate cost estimates can be prepared.

It is important that cost estimates be updated to reflect changes, because large changes in the cost of an acquisition significantly influence decisions to continue, modify, or stop a program.

Performing a cost-variance analysis to account for cost changes is an integral part of revising a cost estimate. This procedure should provide a record of what has happened and what is happening to a program (cost track) and should provide management (decisionmakers and reviewers) with better visibility to control the acquisition process. To be effective the cost track should include, as a minimum, the following steps.

- Comparing and calculating the differences between estimates.
- Determining and documenting the causes for the cost change

Following are some examples of instances where estimates were revised periodically and differences were explained and some where these were not adequately done.

Adequate application of criterion

A-X aircraft

During the period from 1967 through April 1971, nine estimates were prepared as part of the regular Air Force program-budget submissions in accordance with an Air Force regulation which provides that a revised cost estimate be submitted whenever there is a change in the amount of the estimates or in the funding requirements. The updated cost estimate for the A-X aircraft program in April 1971 reflected revised funding requirements resulting from a change in the quantity of production aircraft to be procured.

The estimated cost of the A-X aircraft program was revised in eight of the nine estimates. Variances were accounted for in terms of program conditions that had changed since a prior estimate.

Inadequate application of criterion

Program 777

Estimates on Program 777, revised to include the effects of major changes, were prepared for submission to higher management. However, detailed variance analyses could be made only back to the time of contract award because supporting data for earlier estimates were not maintained. Complete program cost-track capability exists, therefore, only back to the program cost estimate at contract award, which makes internal or external review of the program practically impossible.

DOD PROPOSED ACTIONS ON COST-ESTIMATING PROBLEMS

On July 31 and September 5, 1969, the Deputy Secretary of Defense issued memoranda outlining his views on the need for improvement in weapon system acquisition and urged the military services to improve their estimating capabilities.

In response, the military services have proposed and taken a number of actions intended to improve the cost-estimating process. Additionally DOD Directive 5000.1 dated

July 13, 1971, was issued. It establishes policy for major defense system acquisition in the military departments and other defense agencies. There are several points included in this directive which indicate DOD's concern for improving the estimating process and which lend credence to the criteria in chapter 2. These points are.

1. Before proceeding into full-scale development, risks should be identified and solutions should be in hand.
2. Traceability of estimates and costing factors, including those for economic escalation, should be maintained.
3. Technical uncertainty should be continually assessed.
4. A single, realistic WBS should be developed for each program to provide a consistent framework for (a) controlling and reporting progress and (b) establishing a data base for estimating the future cost of defense systems.

CHAPTER 3

GENERAL OBSERVATIONS, CONCLUSIONS,

AND RECOMMENDATIONS

Our review convinced us that there were many problems associated with the cost-estimating process for acquiring major weapon systems. However, it is important to note that the Secretary of Defense is aware of many of these problems and has given instructions designed to bring about improvement. Because these instructions were in various stages of implementation, we did not attempt to evaluate their effectiveness. This will be an important matter to be covered in future reviews.

We believe that many of the problems we observed stemmed from the absence of specific direction within all levels of DOD. Particularly troublesome was the spotty guidance provided to estimators to assist them not only in determining what should be done to prepare reliable estimates but also in disclosing what actually was done. Guidance provided often was not implemented.

ESTABLISHMENT AND EXECUTION OF A PLAN

Because of the complex nature of acquiring weapon systems, a disciplined approach is needed in estimating the cost of those weapons. In the cost-estimating process, there is a need to

- 1 State clearly what is to be done.
2. Assign responsibility for performance.
- 3 Schedule the accomplishment of tasks.
4. State precisely the criteria to be used for the completion of each task.
5. Coordinate all required tasks.
- 6 Allocate the proper amount of resources for performance of the tasks.

These requirements dictate the need for written procedures, both general and specific, for weapon systems, to insure common understanding of the estimating process throughout the Defense Establishment. A natural fallout of compliance with written procedures which state what should be done would be documentation of what actually was done in the estimating process and how and why it was done. Our review showed many instances where formal procedures had not been established, consequently the practices followed in preparing estimates varied widely.

WHAT SHOULD BE DONE?--A WRITTEN PLAN

Although some written guidance existed in DOD, the adequacy of this guidance and the extent to which it was applied varied considerably. Within the Office of the Secretary of Defense, there was no official document to guide the services in cost estimating. A directive entitled "Cost Analysis Program" has been in draft form for some time but has not been issued. It has been Office of the Secretary of Defense policy to issue general guidance rather than to dictate specific procedures.

Department of the Navy directives indicate that cost estimates should be completely documented, but the directives provide little guidance on how the estimates should be prepared.

The Naval Material Command provided little guidance on the cost-estimating process to its various systems commands involved in weapon acquisitions and left it to the individual commands to formulate their own guidelines. As a result practices and procedures within the Naval Material Command have been inconsistent.

The same pattern existed within the subordinate systems commands. For example, guidance provided by the Naval Air Systems Command and the Naval Ordnance Systems Command stressed that cost estimating be complete, consistent, well documented, and explicit in content and purpose but did not provide specific guidelines which could be used by the cost estimators to achieve those objectives.

Our review of cost-estimating practices in the Department of the Navy was concerned primarily with the Naval Air Systems and Ordnance Systems Commands. However, our previous reviews showed that the Naval Ship Systems Command and the Naval Electronic Systems Command recognized the need for improving their cost-estimating capabilities and had initiated various projects to improve these capabilities.

Historically the Department of the Army has provided little guidance for preparing cost estimates. Recent efforts by the Department of the Army under the pilot program for improved cost estimating have provided guidance for documenting the estimating process.

Guidance and direction by the Army Materiel Command prior to 1970 was limited and did not provide a disciplined system for insuring the validity of cost estimates or uniformity of cost estimates made by the various commodity commands. Late in 1969 the Army Materiel Command initiated a pilot program for improving cost estimating and issued detailed instructions for the preparation of estimates. This pilot program has been completed and is now being implemented throughout the Department of the Army.

The Department of the Air Force has issued detailed guidance on preparing cost estimates. The Air Force Systems Command issued detailed instructions on preparing cost estimates in November 1967. A manual on this subject addresses identifying tasks, using WBS, obtaining and evaluating data, and using various estimating techniques. Our review showed that this guidance was not being consistently applied by Air Force estimators. The extent to which these procedures were applied varied from a limited application to complete application.

DOCUMENTATION OF WHAT WAS DONE

One of the problems affecting the cost-estimating process was inadequate supporting documentation. In virtually every estimate we reviewed, documentation of what was done, and why, was clearly lacking. This hindered the understanding and proper use of the estimate.

Cost estimates for a specific system are frequently a succession of revisions with the current cost estimate derived by refining and revising the previous cost estimate. Our review indicated that estimate revisions had been made without complete documentation to provide the estimator with basic information on data sources, assumptions, methods, and all other decisions basic to the estimate.

The effects of this "mixed bag" of cost-estimating procedures and practices are illustrated repeatedly in our discussion of each of the criteria and related examples in chapter 2. Our observations with regard to the individual practices we believe to be critical to an effective estimating process follow.

1. Prior to the actual preparation of a cost estimate, the estimator must know the purpose and scope of the estimate, the system description, and what the ground rules will be during the preparation of the estimate. We found that the estimator usually was furnished with adequate information on these items.
2. One of the most beneficial ways to insure that a cost estimate includes all pertinent costs is to require all agencies and contractors expected to incur significant costs in support of a program to estimate the costs for their parts of the program. Our study indicated that the military services were gathering input from contractors and Government agencies supporting a program.
3. Data used to estimate the cost of a weapon system must be suitable for purposes intended. They should be current, unbiased, and directly related to the system's performance characteristics. Cost estimates we reviewed frequently did not fully identify source

data used to derive the estimate, and when it was identified, the data used were not always representative, valid, or reliable. We believe that a factor contributing to this situation was a general lack of historical cost data on weapon systems.

4. Use of DOD's standardized WBS, which subdivides the total acquisition task into specific work packages for organizing cost estimates, insures that estimates can be related in a meaningful way to the total acquisition effort. It also helps to preclude the omission of costs and serves as a vehicle for the constant refinement of costs as the program progresses. Current practices range from complete utilization to almost complete disregard of WBS. Most estimates made some use of WBS, but not to the extent sufficient to realize maximum benefits.
5. Failure to realistically identify the risks involved in a program and to anticipate the costs necessary to resolve such problems could easily result in a significant understatement of the estimated costs to develop and produce a weapon system.

For those systems in our review, we generally found that provisions had been made in the cost estimates for resolving uncertainties then known. Engineering-risk analyses, technical feasibility studies, or other methods of risk identification generally had been made. However, in some of these cases it was not clear whether all known risks had been provided for in the estimates.

In addition, while a weapon system is being developed, there is no way to determine, with certainty, whether the amounts provided in the cost estimate for resolving high-risk areas were adequate. In the past the estimates were prepared on the assumption that technical objectives would be met as planned. No provision was made for unanticipated difficulties.

However, a different approach was taken in the most recently updated study of the SAM-D. The Army

provided for technical uncertainties in the program and developed an allowance for their cost impact. This was done primarily by a statistical-estimating method which computed the research, development, test, and evaluation costs for the system on the basis of historical costs of other systems. This estimating method, termed "study of trends and escalation of costs," assumed that the SAM-D would follow the trend of previous systems and that a median level of past problems, e.g., schedule slippages and unforeseen technical problems, would persist.

6. A provision for inflation results in a more realistic estimate and consequently in a reduction in cost growth attributed to this factor. DOD and the military services attempted to include a provision for inflation, however, the methods used to estimate inflation and the extent to which inflation was recognized and set forth in cost estimates varied considerably.

We observed that inflation had been excluded from older program estimates and that the more recent estimates frequently made some provision for inflation. However, the methods used to compute inflation in the more current program estimates were not always ascertainable or consistent.

The trend toward inclusion of inflation factors in program estimates is responsive to the Secretary of Defense's memorandum dated May 6, 1969, in which he stated that the program cost data should reflect the ultimate cost, regardless of contract target or ceiling costs. The policy was amplified by the Assistant Secretary of Defense (Comptroller) to provide for economic escalation in program cost estimates. DOD is continuing to work on this problem.

7. Certain costs sometimes are omitted from particular estimates because of the intended use of the estimate. It is important to show such action and to fully explain the reason therefor. Our study of program estimates revealed that in numerous cases known costs had been excluded without adequate explanations. In those cases where excluded costs

were shown the justification given usually was invalid.

8. Effective independent review of cost estimates is essential to insure valid and reliable estimates. Most organizations have established procedures for reviewing the estimates; however, the process is relatively ineffective due to the lack of adequate supporting information for an estimate and/or to a lack of independence in the review function.

For the acquisition programs we reviewed, changes in the estimating category almost always were increases. In other words, estimates were consistently understated. It seems reasonable to expect estimating procedures and techniques to cause as many overstatements as understatements, but this was not the case.

Without realism and objectivity in the cost-estimating process, bias and overoptimism creep into estimates prepared by advocates of weapon systems and the estimates tend to be low. Therefore persons who are not influenced by the military organization's determination to field a weapon system, or by the contractor's desire to develop and produce the system, should review every weapon system at major decision points in the acquisition cycle.

In 1969 the Deputy Secretary of Defense emphasized the need for independent Government cost-estimating capabilities in the Office of the Secretary of Defense and in each of the military services as a primary means of reducing overoptimism in estimates made by both the contractors and the agencies in DOD sponsoring a new weapon. However, this capability has yet to be established within DOD, and primary action taken by the military services has been the issuance of policy statements advocating an independent validating capability

9. The estimate must reflect the latest data available to realize maximum benefits. Therefore a procedure for the prompt revision of estimates is needed. It should include provisions for a cost track and for a variance analysis so that there will be a record of cost changes. For the majority of systems in our study, estimates had been revised as required. In

a number of cases, however, cost tracks and variance analyses were inadequate, were not available, or had not been prepared.

10. Documentation of the cost-estimating process is an integral part of estimating practices and procedures. Documentation is essential for an effective independent review of the cost estimate to insure validity and to provide for an informed application of the costs projected through the estimating process. However, in virtually every system we reviewed, documentation of what was done, and why, was clearly lacking. This not only hindered the understanding and proper use of the estimate but also left the review process open to question.

RECOMMENDATION

The Secretary of Defense should develop and implement DOD-wide guidance necessary to provide a basis for a disciplined cost-estimating process. In developing this guidance, he should consider the criteria for cost estimating set out in this report. Of particular importance are

1. An adequate data base of readily retrievable cost data.
2. Treatment of inflation.
3. An effective independent review of cost estimates, including judgment by top officials as to the realism of the cost estimates on which decisions are based.
4. More complete documentation of cost estimates, coupled with a requirement for an adequate feedback of results, to provide a basis for comparing costs achieved with those estimated.



ASSISTANT SECRETARY OF DEFENSE
WASHINGTON D C 20301

1 FEB 1972

SYSTEMS ANALYSIS

Mr Hassel B Bell
Associate Director
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General Accounting Office
Washington, D C 20548

Dear Mr Bell

We have reviewed your Draft Report on "Theory and Practice of Cost Estimating for Major Acquisitions - DOD" of October 28, 1971. Your report concerns itself with the need to have "realistic cost (estimates available as a valuable tool for) Congress and Agency managements for program selection, evaluation, and cost control during the weapon system's acquisition process ". The report finds that there is a "need for a plan stating what should be done and then documenting what actually was done ". It states that " among the difficulties resulting are

- "-- Known costs have been excluded without adequate or valid justification
- "-- Historical cost data used as a basis for computing estimates was sometimes invalid, unreliable, or unrepresentative
- "-- Inflation was not always included in cost estimates or uniformly treated when it was included
- "-- Cost estimates were not adequately documented thereby hindering the understanding and proper use of the estimate
- "-- Independent in-depth reviews were usually non-existent

"There is a general lack of readily retrievable cost data which could serve as a basis for computing cost estimates for new weapon systems "

Recognition is also given in the report to efforts being undertaken within the Department to improving our cost estimating capability. The

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report also "recommends that the Secretary of Defense develop and implement DOD-wide guidance for consistent and effective cost estimating procedures and practices. In formulating this guidance, consideration should be given to the criteria for cost estimating set out in this report. Of particular importance is provision for

- a. an adequate data base of readily retrievable cost data
- b. uniform treatment of inflation
- c. an effective independent review of cost estimates
- d. more complete documentation of cost estimates
- e. dependable program definitions.

BEST DOCUMENT AVAILABLE

The Department has been aware of the need to improve the quality of our cost estimates and we believe that we have already taken significant steps in this regard. We also concur in the general GAO conclusion that many of the problems that still exist stem either from the lack of specific guidance or the failure to implement effectively existing guidance. In order to overcome the former problem, we plan to provide the necessary guidance to the DOD components. This would include criteria to guide those charged with making estimates and would establish procedures to have cost estimates, which were prepared within this guidance, available for use by the Services and the Secretary of Defense. In addition, it would provide guidance necessary for the creation and maintenance of data systems for cost estimates. To meet this same objective, the Deputy Secretary of Defense has recently issued a memorandum requiring that the Services prepare independent parametric cost estimates prior to the convening of DSARC's. While the Services will have prime responsibility for reviewing these estimates, Assistant Secretary of Defense for Systems Analysis will make sure these estimates are properly reviewed and evaluated.

In addition the Services have all taken steps to improve their cost estimating capability. For instance, the Department of the Navy has established a Resource Analysis Group (OP-96D) that currently consists of eight professionals and is being expanded to fifteen. The Department of the Army is appointing a project manager who will be responsible for development of an independent parametric estimate for each system covered by a SAR or subject to a DSARC review. This project manager will also be responsible for providing leadership and direction to the estimating effort and for overseeing quarterly in-process reviews (IPR) of these parametric cost estimates. The Air Force Systems Command is about to reissue its Cost Estimating Manual (AFCSM 173-1) which will include all the criteria for good cost estimates discussed in your report. This manual which applies to all major acquisitions goes beyond those recommendations in its treatment of cost estimating methodology, documentation (including assumptions) and risk analysis.

We have just given wide circulation to a RAND book on "Cost Considerations in Systems Analysis" and are also about to give wide circulation to

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another RAND textbook entitled "Military Equipment Cost Analysis " These textbooks should substantially supplement the cost analysis training already being provided by the Air Force Institute of Technology at Wright Patterson AFB, Ohio, and the Army Management School at Fort Lee, Virginia

The Department also recognizes the need to provide guidance on the treatment of inflation in weapon system cost estimates, and we are in agreement with the GAO's conclusion that such assumptions need to be made explicit. Specific guidance has already been prepared for the inclusion of such estimates in the Five Year Defense Program. The policy does not however require the use of a uniform rate of inflation as suggested by your report. The approach we have adopted assures that acquisition programs can be costed so as to realistically reflect the inflation that each specific program is anticipated to encounter. Thus, factors such as the specific industrial sector involved, regional or local labor rates, specific contractual clauses on escalation, etc., can be taken into account. We also recognize that more analytical work needs to be done to provide a better basis for the inclusion of inflation in cost estimates. This has been discussed in more detail in our comments on your report entitled "Feasibility of Constructing Weapon System Prices Indexes "

We also recognize the importance of improving the historical cost data base that is necessary to make cost estimates on future weapon systems. As you know, the DOD has in existence Cost Information Reports (CIR) to collect actual costs on similar weapons on a comparable basis, so that this information can be used for cost analysis purposes. CIR is currently being collected on aircraft, missiles and space vehicles. Another reporting system, Procurement Information Reports (PIR) has been established to collect actual costs on less expensive weapon systems. The Department currently has a study under active review which is considering ways to (1) expand the collection of actual costs to other classes of weapon systems such as ships and tracked vehicles, (2) consolidate existing reporting systems, and (3) assure the comparability of cost data collected by new systems with costs being collected by existing reporting systems.

We also agree that known costs should not be excluded without valid justification or proper identification. The use of parametric cost estimating techniques is intended to minimize the possibility of not considering all likely costs since such a cost estimate is based on a statistical relationship to the actual cost of similar weapon systems. In some cases, however, certain costs eventually incurred, were properly not included in the initial estimates. Such a situation arises, for example, when a decision is made to expand the performance capability of weapon systems after preparation of the initial estimates.

The Department also recognizes that there is need to properly document all cost estimates in order to make clear how these estimates were

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made and the basic assumptions used in making these estimates. We believe there should be a requirement to prepare such documentation -- but it should be recognized that the specific form this documentation takes will vary somewhat as a function of the scope and direction of specific cost analyses.

We believe the report has done a good job of reviewing the status of cost estimating for major weapon systems. The Department agrees with the report's basic conclusion that there is a need to make better cost estimates and insure their use in the decision making process. We have already taken many steps to improve our capability in this area and are taking active steps to continue to improve our capability in this important area.

The Department also recognizes the need to make cost an integral design parameter. DOD Directive 5000.1, Acquisition of Major Defense Systems, 13 July 1971, states that system development shall be continuously evaluated against "design to" requirements factors, such as unit production cost, with the same vigor as that applied to technical requirements. We are currently preparing a DOD "Cost-to-produce" Handbook to provide guidance in this area. This effort should be completed by late spring 1972. This approach will foster tracking of future production costs as the final design evolves to permit corrective action in high cost areas in a more timely fashion than in the past.

Sincerely,



for Gardiner L. Tucker
Assistant Secretary of Defense

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