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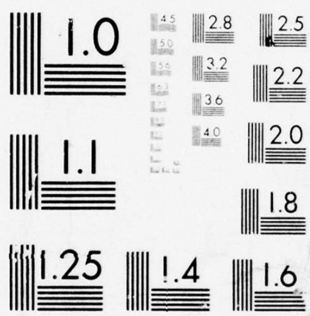

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THE AIR FORCE COST ESTIMATING PROCESS: THE AGENCIES INVOLVED AND ESTIMATING TECHNIQUES USED

Edwin M. Lewis, Major, USAF
Eugene D. Pearson, Major, USAF

LSSR 5-77A

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The Department of Defense is faced with the task of acquiring new weapon systems. These acquisitions have been characterized by a history of cost growth, while disparities exist among the cost estimates that are made by different organizations. The AF Business Research Management Center believes that few individuals have an overall, detailed perception of how the various cost estimates interrelate and this belief was substantiated by the research. An extensive literature review was accomplished. A model of the Cost Estimating Process as it appears in published sources was developed, including specific estimating techniques used. An attempt was made to validate this model against the "real world" through approximately 80 interviews with cost estimators from all organizations and levels involved in the cost estimating process. When the interviews failed to validate the literature model, a more appropriate model was constructed. Four factors were identified which need attention if the accuracy of estimates is to be improved: (1) a standardized definition of "accuracy"; (2) a feedback system tailored to the individual estimator; (3) a compendium of cost estimating techniques; (4) a standardized data base identifying the estimator, project, techniques used, and time frame of the cost estimate.

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THE AIR FORCE COST ESTIMATING PROCESS: THE AGENCIES INVOLVED AND ESTIMATING TECHNIQUES USED

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

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In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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CHAPTER I

INTRODUCTION

The Department of Defense (DOD) is faced with the task of acquiring new weapon systems to maintain the United State's position as the leader of the free world. The acquisition of these new weapon systems has been characterized by a history of substantial growth in actual costs relative to earlier estimated program costs (1 ; 11 ; 18; 25). In the last decade this cost growth in the acquisition of Air Force weapon systems by the DOD has become a major problem for the DOD, Congress and the American people (18). Martin defines cost growth as " . . . when actual cost is greater than the initial estimate for a program [18:84]."

Another area that causes chagrin is the disparity among the cost estimates that are made by many different Air Force and DOD organizations. During his tenure as Secretary of Defense, Mr. Laird emphasized the critical importance of valid cost estimates by establishing the Office, Secretary of Defense Cost Analysis Improvement Group (OSD/CAIG). He stated, "Service groups responsible for independent estimates and the OSD Cost Analysis Improvement Group should work closely in developing uniform criteria for cost estimates [31]." Presently the Controller of the Air Force (AF/AC) and the Director of Procurement Policy

(AF/LGP), Headquarters USAF are making studies of the different estimating groups so they can understand and reduce disparities in cost estimates made by the variety of different organizations involved in estimating the costs of new weapon systems (15; 59).

The Air Force Business Research Management Center has been established to coordinate research particularly relevant to managing the Air Force procurement function. It monitors the different research efforts being accomplished to provide a focal point for information and limit unnecessary duplication. It is the Center's firm belief that very few, if any, individuals have an overall perception of how the variety of major weapon system cost estimates interrelate and what causes the wide variances that seem to exist among the different estimates made by the different organizations (26).

Statement of the Problem

There is a need to better understand as an overall process how cost estimates for new weapon systems are developed in the Air Force, who develops them, and the contribution each estimate is designed to make in the overall acquisition process. A thorough analysis should help explain why Air Force cost estimates for the same weapon system vary so much from each other and from the actual, final cost of the weapon.

Background

The weapon system acquisition process begins when the need for a new weapon system is first identified, and it continues through the conceptual, validation, development, and production phases (18:16). At many points during the process, different agencies are required to make estimates of what the new weapon system will cost (53). Most of the major cost estimates are used principally to justify and to support proposals to the Defense System Acquisition Review Council (DASRC), which in turn determines whether to proceed with or terminate the weapon system development (11:5). The cost estimates are also used to justify and to support proposals to Congress in efforts to obtain and retain congressional approval of funding. When there is an increase in the cost of the program, as measured by the differences between the development cost estimates and the actual cost of the program, the DOD must explain why and is frequently severly criticized for its inability to control acquisition programs (11:9; 16:5).

Multiple estimates are made by different agencies using different techniques (26; 53). The cost estimates provided by the DOD in support of new weapon system proposals frequently turn out to be inaccurate (27:40). The subsequent cost overruns result in considerable Congressional and public concern reflected in a loss of confidence in the DOD estimating ability and in future program justification efforts (27:40-44).

Justification

The DOD, if it is to regain Congressional confidence and support for existing and future weapon system programs, must improve the cost estimates used to support proposals brought before Congress. It is essential not only to acquire new weapon systems at minimum cost, but to accurately predict the cost of these weapons when advocating them. Only with accurate estimates can the Air Force, DOD, and Congress make appropriate and logical cost tradeoffs among the weapon system programs competing for defense dollars, and thus insure the most effective use of the scarce U. S. tax dollar (22:8; 27:20).

Mr. Laird, while serving as Secretary of Defense, stated that valid cost estimates are critical to a successful defense posture (31). Professor Bruce Baker carried this a step further in the concluding remarks of his 1972 doctoral dissertation, stating, "It can be surmised . . . that as original estimates become more realistic, greater pressure will exist to stay within those original estimates [2:124]." The pressure to stay within the original estimates and to reduce cost overruns is present now, even though these estimates may not have become more realistic or accurate. Congress has reduced the percentage of the federal budget allocated to the DOD from 60 per cent in 1954 to approximately 30 per cent in 1974 (8:10). This is partially due to the fact that the American public has been demanding and receiving a larger share of the federal budget for social programs such as aid to education, welfare and health care (8:10), but it may also be due partially to a perceived inability of the DOD to control its weapon system acquisition process (21:49).

In 1974, Secretary of Defense James Schlesinger stated that the defense policy of the United States would continue to be one of maintaining " . . . a reasonable stable level of defense effort . . . [24:4]." Thus it would seem that the DOD must continue to arm itself with new weapon systems to meet future threats, but with an apparently reduced buying power. To do this it must regain Congressional confidence in its ability to make accurate cost estimates.

After interviewing several personnel interested in the estimating process (14; 15; 26), it is evident that a variety of opinions exist as to how the DOD estimating process works. An analysis of their comments indicate that there are conflicts regarding who makes cost estimates on new weapon systems and what techniques are used to make these estimates at various points in the weapon system acquisition process. Misconceptions are also evident in regards to comparisons between cost estimates made in the conceptual phases and estimates made in the production phase.

Objective

The objective of this study is to clarify and document the overall cost estimating process used by the Air Force in the acquisition of new major weapon systems.

Research Questions

The following research questions are posed to guide the research toward the stated objectives:

1. What model of the cost estimating process for new major Air Force weapon systems can be developed that depicts

   a. the organization/agency providing each cost estimate,

   b. the purpose for which each cost estimate is developed,

   c. the point in the acquisition process where these estimates are made, and

   d. the techniques which are appropriate to each organization/agency in producing their estimates, considering the information available at the point when the estimate is needed?

2. If such a model can be developed, can it be validated to demonstrate that it realistically reflects the "real world" estimating environment of the agencies concerned with the acquisition of new major Air Force weapon systems?

Study Approach

Research Question number 1 will be answered by a thorough literature review in Chapter II. This literature review will include AF and DOD regulations, manuals, pamphlets, directives, and other publications as applicable.

The methodology for validating the model will be presented in Chapter III. The answer to Research Question number 2 will be developed in Chapter IV using the methodology presented in Chapter III. Finally, Chapter V will contain the conclusions reached as a consequence of this research effort and the recommendations the authors have for implementing the results and for needed future research.

CHAPTER II

LITERATURE REVIEW

A literature review was conducted to answer Research Question number 1. A model of the cost estimating process used by the Air Force in the acquisition of new major weapon systems was developed. The literature review covered the appropriate regulations, manuals, directives, and other publications available to define:

1. the Air Force weapon system acquisition process and phases;

2. the sources of cost estimates made within this process;

3. the type of estimate made or purpose for which an estimate is developed by each organization/agency during the phases of the weapon system acquisition process;

4. the amount of data available during the different phases of the weapon system acquisition process to make cost estimates; and

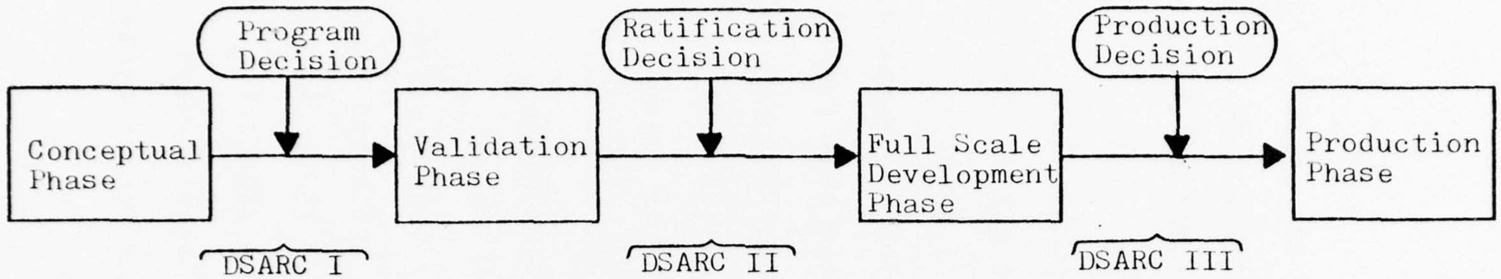
5. the techniques used by the agencies to make their cost estimates.

These five areas were considered the major concerns in developing a model of the cost estimating process for acquiring new major Air Force weapon systems. The model developed through this literature review is presented in Figure 2 at the end of this chapter.

Weapon System Acquisition Process

The process by which weapon systems are acquired by the Air Force is termed the weapon system acquisition process. This weapon system acquisition process is composed of six (6) phases: (1) the conceptual phase; (2) the validation phase; (3) the full scale development phase; (4) the production phase; (5) the deployment phase; and (6) the reutilization and disposition phase (60:2-3). Cost estimates dealing with system acquisition are normally made in the first four phases. Cost estimates made for optimal system deployment and for the reutilization and disposition of the system are beyond the scope of this research effort. Therefore, only the first four phases will be considered in this study. (See Figure 1 for a graphic presentation of the weapon system acquisition process).

DOD Directive 5000.1 defines a major weapon system as one whose program dollar value will have an estimated Research Development Test and Evaluation cost in excess of 50 million dollars or an estimated production cost in excess of 200 million dollars (29:1). For this research project, only major weapon systems within the weapon system acquisition process are considered.



Conceptual Phase:	Technical, military, and economic bases are established; alternative approaches identified; data gathered to support proceeding with the program.
Validation Phase:	Major program characteristics are validated and refined; program risks assessed, resolved or minimized; performance specifications established.
Full Scale Development Phase:	Complete weapon system defined; system design, fabrication, and tests are completed; system documentation prepared.
Production Phase:	The system is produced and delivered for operational use.

Figure 1

Phases of the Acquisition Process (36:1-1 - 1-3)

Conceptual phase. During the conceptual phase, an operational requirement for a new weapon system is identified (11:5). This need is normally defined by an operational command, but others do identify need requirements. Contractors, military study groups, and organizations such as RAND, Analytical Systems Incorporated, and MITRE also identify such needs (60:10-22). Regardless of who initiates the identification of the need for a new weapon system, official recognition of the requirement begins with the preparation and submission of a Required Operational Capability (ROC)(60:10-24). A ROC is submitted to Headquarters, USAF under the provisions of AFR 57-1 (34). AFR 57-1 defines a ROC as "a formal, numbered document, used to identify an operational need and to request a new or improved capability for the operating forces. The capability sought is described in terms of operational objective, operational environment, support and maintenance concepts, and concept of operation [34:2]." The ROC provides the information and supporting rationale necessary to develop a thorough understanding of the deficiency to be alleviated and the corrective action proposed (60:10-27).

The Conceptual phase has three objectives (12:24): (1) to establish the military, technical, and economic basis required to support a decision on whether to acquire the new weapon system; (2) to identify the alternative approaches available and select the preferred one; and (3) to gather data and make a detailed analysis which will support a decision to proceed with the acquisition process. Portions of this data are used to make cost estimates (12:24). This analysis and a plan for the program are documented in a Development Concept Paper (DCP) which is reviewed by the Defense Systems Acquisition Review Council (DSARC)(60 :2-4).

The DSARC was established to provide the Secretary of Defense with information and recommendations on the status and readiness of each major weapon system concept in order to proceed into the next phase in the acquisition process (31:4). In the conceptual phase, the DSARC must make a decision (DSARC I-Program Decision) whether to recommend to the Secretary of Defense to proceed into the validation phase or to reject the system as proposed (60:2-4).

Validation phase. In the validation phase the technical, schedule, and cost requirements of the weapon system are refined and validated (12:25). The objective of the validation phase is to establish firm and realistic performance specifications which meet operational requirements (12:25). This phase is normally conducted by the Air Force working with two or more contractors (if possible) who are interested in performing the full scale development and production of the weapon system (11:5). The contractors, working independently of each other, present design proposals for consideration by the Air Force (11:7).

Once again, a DSARC decision (DSARC II-Ratification Decision) must be obtained in order to proceed to the development phase (12:26). DSARC II reviews the program with respect to the technical risk involved, the time required to obtain a completed weapon system, and the estimated cost of the weapon system (11:7).

Full scale development phase. The objective of the full scale development phase is a completely defined weapon system in terms of technical performance, schedule, and cost (11:8). A limited number of working models (prototypes) are fabricated during the full scale development phase. These hardware models are used to provide actual performance demonstrations and verify the weapon system design. The documentation necessary to produce the weapon system for inventory is also identified and is developed during this phase (12:27).

The culmination of the full scale development phase is the DSARC III decision (production decision). The DCP is updated and the DSARC determines whether or not to recommend full scale production and deployment of the weapon system. It must also determine the initial quantity to be produced and approve plans for future production (12:28). DSARC III is the last chance to stop the new weapon system prior to full scale production (53:2-4).

Production phase. In the production phase, the weapon system and its support equipment are produced for operational use (12:28). During this phase, responsibility for support and use of the weapon system is gradually transferred from Air Force Systems Command (AFSC) to AFLC for support and to the using command for operations. Operational testing takes place during this phase. Production and deployment of the weapon system occur simultaneously and may continue over long periods of time (11:8).

Cost estimates are made in each of the phases of the weapon system acquisition process to support proposals made to the DSARC. The DSARC considers the validity of the cost estimates in making their decision on whether to proceed to the next phase or to stop the program (31:7). The phases of the weapon system acquisition process can thus provide the basis for identifying when cost estimates are made and the amount and kind of data available for making cost estimates on new weapon systems.

Sources of Cost Estimates

Four forms of cost estimates are developed during the weapon system acquisition process. These estimates are the Cost Analysis Improvement Group (CAIG) estimates; Independent Cost Estimates (ICE); Air Force Systems Command System Program Office (SPO) estimates; and contractor estimates or proposals (19:1).

Cost Analysis Improvement Group. The CAIG was established under the office of the Secretary of Defense (OSD) by DOD Directive 5000.4. The primary responsibility of the CAIG is to " . . . act as an advisory body to the DSARC on matters relating to cost [31:2]." The CAIG provides the DSARC with:

1. a review and evaluation of independent cost analysis provided by the MAJCOM performing the Independent Cost Estimate and program cost estimates provided by AFSC, to include all elements of system costs;

2. criteria, standards, and procedures concerning preparation and presentation of cost estimates; and

3. an assessment/recommendation on cost objectives prior to including them in approved DCPs (31:2).

The CAIG is also responsible for developing methods, techniques, and policies to improve cost estimating by DOD components and to resolve issues arising over the comparability and completeness of cost data (31:2).

The OSD CAIG reviews and evaluates all cost estimates prior to their submission to the DSARC for review (60 :10-46). This review and evaluation takes place at the completion of the conceptual, validation and full scale development phases of weapon system acquisition (60 :2-4). The OSD CAIG resolves any differences between the ICE and the SPO estimates. In this context, it provides an estimate of its own to the DSARC (31 :2).

Air Force Systems Command. AFSC Manual 173-1 establishes the requirements for the Aeronautical Systems Division (ASD), Electronics Systems Division (ESD), and the Space & Missile Systems Organization (SAMSO) to make cost estimates in support of planning and program/budgeting activities associated with the concept formulation, development, and acquisition of new weapon systems (33:1.1).

ASD has primary responsibility for planning, developing, and acquiring aeronautical systems including aircraft and air launched missile weapon systems. ESD has primary responsibility for planning, developing, and acquiring all major electronic systems. SAMSO has the primary responsibility for planning, developing, and acquiring all ballistic missile and space systems (45:7-9). These organizations establish a System Program Office (SPO) to monitor and manage each weapon system. One principal responsibility of each SPO is to develop an official program cost estimate for AFSC (42).

Cost estimates by the appropriate system program office are prepared at any time throughout the weapon system acquisition process, but are mandatory at three significant points in the process. These points are just prior to the three DSARC milestones and in preparation for the DSARC review and decision (33:1-4).

Independent Cost Estimate. Air Force Regulation 173-11 establishes the procedures for the Independent Cost

Analysis (ICA) Program (35). An ICA is a cost estimate made independent of the official (SPO) program cost estimate. The purpose of the Independent Cost Estimate (ICE) is to provide a test of the reasonableness of the SPO program estimate. To insure that the ICE is not a repeat of the SPO estimate, the techniques used to prepare the ICE must be different than those used to prepare the SPO estimate (35:1).

HQ USAF, Directorate of Management Analysis designates which major command will have the responsibility for preparing the ICE. The designated major command provides the team members, as required. It must also insure that the SPO provides the program, contract, technical, and cost data required by the team to perform the ICA and make the ICE (35:1). The team preparing the ICE must be organizationally separated from the SPO managing the system. No member participating in the preparation of the ICE may have participated in the preparation of the SPO estimate for the same weapon system (35:1).

An ICE is prepared on a major weapon system for each DSARC milestone. The major command designated to perform the ICE is notified approximately 65 workdays prior to the DSARC review. The results of the ICE are presented to the OSD CAIG ten workdays prior to the DSARC review (35:3).

Major commands. AFR 57-1 establishes the procedures and assigns the responsibilities for writing ROCs for new and improved operational capabilities (60:10-24).

It tasks AFSC and/or AFLC with the responsibility to prepare budget cost information. Budget cost information is defined as "Information on proposed alternative solutions, costs, and schedules for satisfying a ROC [34:2]."

AFSC is specifically tasked to provide preliminary cost estimates, to include life cycle cost projections if available, for those ROCs requiring a research or development effort (34:3). AFLC is specifically tasked to provide cost estimates for those ROCs that can be satisfied by modification to a configuration item (34:3).

Contractor proposals/estimates. The defense industry is composed of approximately 22,000 prime contractors and 100,000 subcontractors (23:57). These contractors are used throughout the weapon system acquisition process to support the Air Force efforts in designing and estimating the cost of new weapon systems as well as producing the weapon system (18:22-33). They provide technical, feasibility, and cost studies to the Air Force in the conceptual phase and cost proposals, budget estimates and cost performance reports in the conceptual, validation, and full scale development phases. Cost estimates of the program's progress and compliance with earlier estimates, in the form of cost performance reports, are provided in the production phase (18:22-36; 53; 60:10-34). These cost estimates are used by the appropriate SPO as a basis for their cost estimates and in tradeoff studies to determine which alternative system to develop to satisfy the operational requirement and/or which design to pursue (53; 60:15-33,34).

Amount of Data Available

Professor Baker, in his doctoral dissertation, "Improving Cost Estimating and Analysis in DOD and NASA", identified Historical Data Problems as a major problem area for estimations. One question in a survey conducted for his dissertation requested information about the principle problems of cost estimating perceived by persons in the field. Twenty three per cent of the 1353 individuals involved in making cost estimates indicated that problems related to the amount of historical data available were the most important problems of cost estimating and analysis. AFSC reponses to the survey indicated 26% (74 out of 285) felt that data availability was the most important problem (2:50-54).

The problems grouped into the category of Historical Data Problems were:

1. data availability and collection problems;

2. lack of accurate, reliable, credible, valid, and current data;

3. lack of data base and/or computerized data bank;

4. insufficient data regarding installing and operating costs; and

5. insufficient data regarding recurring vs. non-recurring costs (2: 51).

Problems involving techniques, tools, methodology, and procedures were also identified as major problems of cost estimating by 26% of the respondents. The specific problems identified within this category all involved a lack of knowledge concerning how and when the various techniques, tools, methodology, and procedures should be used (2:50-54, 115-117).

Captains Barga and Poch in their technical memorandum for the Air Force Aero-Propulsion Laboratory indicate that during the conceptual and validation phases of the acquisition process, there is often a lack of adequate, complete or firm system definitions. The specifications, drawings and statements of work are not available in detail, because the decision of which alternative design to use has not yet been made. The weapon system design is still undergoing research and development. Because there is a lack of complete data and only historical data on analogous systems is available during the conceptual and validation phases, a parametric approach to cost estimating should be used (3:3,19). More information becomes available during the full scale development and production phases. Additional data on system specification and performance requirements become available as the weapon system is better defined. More identification and prediction of the information not available is also possible during the full scale development and production phases (3:19-22). For this reason, more accurate methods of estimating weapon systems costs can be used. A detailed engineering approach becomes possible during the full scale development and production phases (3:19).

The amount or level of data available to make cost estimates, as described by Baker and Barga (2:50-54) and Poch (3:3, 19-20), can be placed on a continuum ranging from little or no hard, factual data available to a highly detailed level of data. For the purpose of this research, the researchers have defined four categories of data levels. These levels are based on the activities taking place in the phase of the weapon system acquisition process, i.e., as the system progresses through the acquisition process, it becomes better defined and moves from a paper concept to an actual item in the Air Force inventory. The four levels of data as defined by the researchers are:

1. VAGUE--In the conceptual phase, there is an almost complete absence of factual cost data on the specific system being worked. The new weapon system is basically a paper system and has not been defined beyond the stage of a requirement for a particular type of weapon system to meet a need (11:4-8; 12:23-29). There is, however, specific data on other weapon systems available for use, but the relation to the new weapon system is questionable (3:3, 19).

2. LIMITED--In the validation phase, the design of the system begins to take shape. More specific information

is available on what the new system will be and what the specifications of the system are (12:23-29). Because this additional information is available, a better comparison to other, previous weapon systems can be made, giving the estimating agencies more, but still limited, data on which to base their estimates (3 :19-22).

3. DETAILED--In the full scale development phase, the system is completely defined and the specifications finalized. Prototypes of the weapon system are developed for testing (12:23-29). It is in this phase, that the majority of detailed data for making cost estimates becomes available. Limited production figures from the prototype production are also available for use.

4. HISTORICAL--In the production phase the full production figures are available in the form of cost performance reports and other accounting reports. At this point, except for changes in the production schedule and future inflation rates, the actual cost of producing the weapon system is easily and accurately projected (11 :4-8; 12: 23-29; 25).

Techniques Used to Generate Cost Estimates

From a review of the available literature it is apparent there is little agreement as to the classification, description and name of cost estimating techniques. Phillip Ostwald has described in detail eight "preliminary methods" (conference, comparison, unordered ranking, unit, expected value, computer simulation, probability, and ordinal scale) and five "detailed methods" (factor, power law and sizing model, standard time data, cost-estimating relationships and marginal analysis) (20:167-217). Tom Bond has described five "basic methods" (list price, cost as a function of cost, cost as a function of performance, item analogy and expert opinion) (5:123-7). C. A. Batchelder has described three "major methods" (industrial engineering, analogy, and statistical) and mentions that one military source states there are two (synthesis and analysis) while another states there are four (analytical appraisal, comparative analysis, statistical analysis, and standards) (4:1-10) R. S. Harrison has described four "basic methods" (empirical, comparative, statistical and standards) (17:4-6). An introductory short course in cost estimating and analysis sponsored by the Comptroller, Air Force Armament Development and Test Center, Eglin AFB, Florida, mentions nine cost estimating techniques (parametric, cost-to-cost, cost-to-noncost, analogous, engineering, industrial engineering, rates and factors, simulation, and trend analysis) and describes four of the "major" ones (parametrics, analogous, engineering and trend analysis) (48:1.7-2.66). The Department of Defense through the Armed Services Procurement Regulation Manual (ASPM No. 1) describes three "more common methods" (round table, comparison, and detailed) (28: 2B28).

As can be seen there are many different techniques used in the derivation of cost estimates. The choice of which technique(s) to use in any given situation is therefore subjective and confusing. The introductory short course Cost Estimating and Analysis gives some assistance in making the choice by identifying four factors to be evaluated before making the choice. These items are:

1. the type of data that is available at the time the estimate is being made;

2. the purpose for which the cost estimate is to be used;

3. the accuracy that is desired/required of the estimate; and

4. the restrictions of time and resources within which the estimate is to be made (48:2.73).

George L. Martin, Executive Secretary of the National Estimating Society (NES), in a letter to the Cost Accounting Standards Board also concludes that there are a large number of techniques to use in the preparation of cost estimates and that the situation should determine the technique to use. He emphasizes that Mr. R. S. Harrison, President of the Atlanta NES chapter, has written a book called How to . . . Manual on Cost Estimating in which he has given six steps to follow in developing a cost estimate. The steps are:

1. Define the work to be done in as much detail as possible and reasonable. This means forecasting the details of the work to be done and the kinds and quantities of materials, parts, and equipment which will be required.

2. Estimate the man hours, material costs, and other cost-producing elements as well as the elapsed time required to perform each detail of the work.

3. Estimate the costing rates and factors for the work to be done.

4. Apply the costing rates and factors to cost-producing elements to establish total plant costs.

5. Evaluate the costs, make any adjustments to the cost estimate that are required, apply the desired profit and other cost factors and prorations or additions, and establish a sales price.

6. Prepare for submittal to the customer [17:3-4].

These steps may seem simple and obvious, but they are basic and worth noting by any cost estimator. No matter what technique or combination of techniques is used, the steps are still valid (15:4). By combining the items to look at and the steps to follow, the technique to use should be almost self-evident.

For ease of handling, the researchers have broken the cost estimating techniques into four main categories (Parametrics, Research and Development, Engineering, and Standards) which correspond to a given phase in the acquisition cycle: Parametrics to the Conceptual phase; Research and Development to the Validation phase; Engineering to the Full Scale Development phase; and Standards to the Production phase. This classification was selected so that the specific technique would be grouped in terms of the data required to apply the technique. These categories correspond to the data available in the various phases of the major weapon system acquisition cycle. The techniques have been placed in categories consistent with the majority of the literature reviewed.

Explanation of individual cost estimating techniques. The following cost estimating techniques are explained as they will be used throughout this research effort. Techniques were combined if their descriptions and degree of input data were similarly explained in the literature. Table number 1 presents a compilation of the cost estimating techniques. This table shows the techniques grouped by category. Because of the widespread use of different names for the same basic technique, the additional names associated with the same or similarly described techniques have been added for the readers convience. The cost estimating techniques are:

1. Analogy Cost Estimates--This method is derived by choosing analogous programs that have already been completed and for which cost data is available. A ratio of the degree of similarity is then defined. The cost estimate is produced by multiplying the similarity ratio by the cost of the analogous project. According to Bond, this is the most common estimating method in use today (5:126). It also requires a high degree of knowledge about the design and mechanization scheme (48:2.58) as well as expertise on the part of the estimator (4:7). Other names for this method are comparative (17; 20; 28); power law and size

Table 1

Estimating Techniques by Categories

Category	Name of Techniques	Additional Names for Techniques	Description of Techniques
Parametric	Analogy	(comparative, power law and size model, factoring, unordered ranking, and unit method)	Similar costs from analogous programs
	Cost Estimating Relationship	(cost as a function of cost, cost as a function of performance, cost to cost, and cost to noncost)	Historical estimating relationships from related programs
	Expert Opinion	(empirical, conference, and round table)	Subjective opinion by an "expert"
	List Price		Catalogue price
	Parametric		Correlating design parameters to historical cost
Research and Development	Analogy	(comparative, power law and size model, factoring, unordered ranking, and unit method)	Similar costs from analogous programs

Table 1 (continued)

Category	Name of Techniques	Additional Names for Techniques	Description of Techniques
	Cost Estimating Relationship	(cost as a function of cost, cost as a function of performance, cost to cost, and cost to noncost)	Historical estimating relationships from related programs
	Expert Opinion	(empirical, conference, and round table)	Subjective opinion by an "expert"
	List Price		Catalogue price
	Parametric		Correlating design parameters to historical cost
	Engineering	(detailed)	Detailed work segment cost estimates
	Marginal Analysis		Costs of product changes
	Simulation		Computer simulations of the "real system"
	Statistical	(grass roots, expected value, probability, and ordinal scale)	Engineering type with gaps filled by parametrics

Table 1 (continued)

Category	Name of Techniques	Additional Names for Techniques	Description of Techniques
Engineering	Engineering	(detailed)	Detailed work segment cost estimates
	Marginal Analysis		Costs of product changes
	Simulation		Computer simulations of the "real system"
	Statistical	(grass roots, expected value, probability, and ordinal scale)	Engineering type with gaps filled by parametrics
	Standard Time Data		Historical standard time/cost by task
	Trend Analysis		Historical trends projected into the future
Standards	Standard Time Data		Historical standard time/cost by task
	Trend Analysis		Historical trends projected into the future

model, where only the size of the item changes (20:171-4); factoring, where the degree of each similarity is called a factor (20:196); unordered ranking (20:171); and unit method (20:174).

2. Computer Simulation Cost Estimating--In this technique,

> Simulation is defined as the manipulation and observation of a synthetic model representative design which, for technical or economic reasons, is not susceptible to direct experimentation. This synthetic model ideally represents the essential characteristics of the real system with the frills excluded [20:177].

Once the simulation is programed in the computer, the "real system" data is entered and the simulation produces the projected cost output.

3. Cost Estimating Relationships (CER)--This method includes cost as a function of cost, cost-to-cost, cost as a function of performance and cost-to-noncost techniques. It uses one or more independent variables which could be related costs, performance characteristics, etc., and derives a cost estimate based upon historical estimating relationships from a related program. Two assumptions must be met for this estimate to be valid. The first assumption is that the new program will be affected in the same way as the original by the independent variable. The second is that the acceptable CER has been established and verified (5:124-6; 13:1-3; 17:5; 20:207).

4. Engineering Cost Estimates--This method is the

most detailed of all the techniques. It involves breaking down the project into detailed work segments which can be individually estimated at an assumed high level of accuracy. These estimates are then summed into a total cost estimate (4 :2; 48:2.60). It has also been called detailed cost estimating (28:2B28).

5. Expert Opinion Cost Estimates--This is a purely subjective technique and is difficult to analyze and substantiate. The expert's opinion must be accepted as valid. The expert must completely understand all of the factors in the problem. This method is best applied on new products which are beyond the technical state of the art (5 :126-7). Another name for this method is empirical cost estimating (17:4). When a group of experts is used, this technique is called the conference method (4:168-9) or round table estimating (28:2B28).

6. List Price Cost Estimate--This method requires that the items to be estimated have a historical price that is available and acceptable. The estimator only has to multiply the units required by the accepted price and the cost estimate is complete. This is the most accurate method (5:123) given that accurate list prices are available.

7. Marginal Analysis Cost Estimating--This type of estimating is used to cost out changes in operations or engineering changes for a product. The change usually involves incremental amounts on relatively large orders

(4 :207-217). The primary tool used in marginal analysis is differential calculus, a tool which is beyond the scope of this study to describe. An excellent explanation can be found in Cost Estimating For Engineering and Management, a 1974 publication by Phillip F. Ostwald (20:207-217).

8. Parametric Cost Estimates--This technique is accomplished by correlating design parameters to historical costs with the use of regression analysis. The results describe cost relationships between the parameters (48:2.24). These relationships applied to the desired parameters will result in the estimated cost.

9. Standard Time Data Cost Estimating--This technique uses historical cost data to find the standard cost or time to complete a given task. Once a set of standards is known, future event schedule/cost can be calculated. The standard for a task is multiplied by the number of times that task must be accomplished. Then all computed values are summed to the final cost estimate (17:6; 20:202-6).

10. Statistical Cost Estimating--This technique is used to estimate the entire job by using major parameters or technical characteristics, such as weight or speed, to obtain costs for major portions or the whole. It is similar to a macro engineering technique with parametrics added to fill in any gaps (17:5; 20:2-3). "This is sometimes referred to as 'grass-roots' estimating [20:2]."

Other names for similar techniques are expected value (20:175), probability (20:181), and ordinal scale (20:183).

11. Trend Analysis Cost Estimating--This technique examines the cost schedule trend patterns during the full scale development and production phases. These trends are then used to project the anticipated cost to complete the contract (48:65).

Categories of cost estimating techniques. As discussed earlier, the amount and detail of data increases across the weapon system acquisition cycle. For this reason, the following categories are based on the amount and detail of data available at the corresponding phase in the weapon system acquisition process.

It should be noted that the techniques used in the earlier phases can be used throughout the weapon system acquisition process. As the amount of available data increases, other techniques become usable that provide increased accuracy. For these reasons the techniques appear in those categories where they will produce their greatest accuracy. The cost estimating technique categories are:

1. Parametric Category--In this category the cost estimates come from relationships which can be developed between historical costs, system physical attributes and/or performance characteristics. The historical costs take into account system growth, engineering changes, program

stretch-outs and any other possible difficulties encountered in comparable programs (13:5.4; 17:4). They have valuable application when:

a. Some performance/design parameters are known but detailed mechanization features are lacking.

b. Gross estimates are acceptable.

c. In the early stages of program development.

d. Quick reaction estimates are needed.

e. Used for cost/performance trade-off studies (48:2.50).

The cost estimating techniques which fit into this category include analogy, CER, expert opinion, list price, and parametric.

2. Research and Development (R&D) Category--In this category the cost estimates are developed by a combination of the parametric and engineering techniques. Data on critical portions of the project is generated through engineering test and research. This data is then used with the engineering technique to develop the costs of these critical aspects of the program. Those parts of the project that are left are estimated using the parametric techniques. The resulting cost estimate therefore falls in the middle as far as detail, time to complete and position in the major weapon system acquisition process are concerned. Its major contribution is that of an improved and updated cost estimate for review at DSARC II (14).

The cost estimating techniques which fit into this category include analogy, simulation, CER, engineering, expert opinion, list price, marginal analysis, parametric and statistical.

3. Engineering Category--In this category the cost estimates are made by

> . . . defining the effort to be accomplished, the schedule it is to be accomplished against, and the materials and processes to be utilized; parceling this information out to the performing organizations who estimate the cost for each work package [48:2.60].

They have valuable applications when:

a. Detailed data is available and detailed estimates are desired.

b. Contractors are calculating bid prices.

c. Time is available to properly complete the process. (This process is time consuming) (48:2.68).

The cost estimating techniques which fit into this category include simulation, engineering, marginal analysis, standard time data, statistical and trend analysis.

4. Standards Category--In this category the cost estimates are developed from historical cost data. Standard estimates are developed by studing this data base and conducting time and motion studies on combinations of these costs (17:6). Other statistical methods such as regression analysis can be applied to this historical data to yield standards which can be used to predict future costs (20:203). Some of the advantages of the standard

estimates are:

a. The data is cheaper and easier to gather.

b. The estimates are more consistent.

c. It is easier to understand its deviation (20:203).

The cost estimating techniques which fit into this category include standard time data and trend analysis.

Summary

Figure 2, Model of the Air Force Cost Estimating Process Within the Air Force Weapon System Acquisition Process, summarizes the literature review. The Air Force weapon system acquisition is used as the time frame upon which the model is built. The agencies identified as making estimates, the type of estimate they make, the type information available to them to make the estimates and the techniques used in making the estimate are presented.

Phase	Agency Making Estimate	Type of Estimate Made (Purpose)	Technique Used to Make Estimate	Type of Information Available
Conceptual	AFSC/AFLC	ROC Evaluation	Parametric	Vague
	Contractor*	Estimate from Studies & Cost Proposals	Parametric	Vague
	SPO*	Budget Estimate & Official Program Estimate	Parametric	Vague
	ICA	ICE	Parametric	Vague
	CAIG	Evaluation	Parametric	Vague
DSARC I - Program Decision				
Validation	Contractor*	Cost Proposal & Budget Estimates	R & D	Limited
	SPO*	Budget Estimate & Official Program Estimate	R & D	Limited
	ICA	ICE	Parametric	Limited
	CAIG	Evaluation	Parametric	Limited
DSARC II - Ratification Decision				

Figure 2

Model of the Air Force Cost Estimating Process Within the Air Force Weapon System Acquisition Process

Phase	Agency Making Estimate	Type of Estimate Made (Purpose)	Technique Used to Make Estimate	Type of Information Available
Full-Scale Development	Contractor*	Budget Estimates	Engineering	Detailed
	SPO*	Budget Estimate & Official Program Estimate	Engineering	Detailed
	ICA	ICE	Parametric	Detailed
	CAIG	Evaluation	Parametric	Detailed
DSARC III - Production Decision				
Production	Contractor**	Cost Reporting	Standards	Historical
	SPO**	Cost Analysis	Standards	Historical

*The contractor & SPO can make more than one estimate during each phase. An estimate is made and revised until time of presentation to the DSARC for a decision.

**The SPO & Contractor personnel make continual on-going cost estimates throughout the production phase.

Figure 2 (continued)

CHAPTER III

METHODOLOGY

Description of Universe and Population

For this research, the universe is defined as the set of all agencies which make cost estimates on DOD weapon systems acquisitions. The population is defined as the set of all DOD agencies which make cost estimates on major Air Force weapon system acquisitions. This includes the OSD CAIG, Major Commands, and System Program Offices.

Description of the Sample

This research was conducted using a selected sample consisting of the OSD CAIG; the Comptroller, AFSC and AFLC; available SPOs from ASD, ESD, and SAMSO; and selected Major Commands presently submitting estimates on major weapon systems currently in the acquisition process. At least three individual estimators (when possible) from each agency will be interviewed to obtain the organizational view and to reduce the problem of individual bias. The sample was selected for it perceived representativeness relative to the population and for the remainder of this study it is assumed that the sample can be considered representative of the population.

The rationale for this assumption is as follows:

1. The OSD CAIG is the same agency in both the sample and the population and therefore, represents a census for that portion of the population.

2. AFSC and AFLC, as applicable, are generally selected as the major command to perform the ICE and prepare the Budget Cost Information on each published ROC. One of these two commands will be responsible for designating the office of primary responsibility (OPR) for each ICE and the team chief for the team performing the ICE. One of these two commands will also be responsible for reviewing all published ROCs and providing cost estimates for those ROCs. The cost estimate provided are used in the evaluation of proposed alternatives. Therefore, inclusion of the Comptroller, AFSC and AFLC as part of the sample should adequately represent the timing and techniques used by major command independent cost estimators. It will also represent the timing and techniques used by major commands to provide cost estimates on the ROCs proposed by agencies which identify requirements for new weapon systems.

3. The AFSC SPOs selected for inclusion in the sample were based on convenience and availability. All current ASD SPOs associated with major weapon systems and a number of SPOs from ESD and SAMSO were selected. This permitted the researchers to sample aeronautical systems including aircraft and air launched missile weapon

systems (ASD), major electronic systems (ESD), and ballistic missile and space systems (SAMSO). A representative sample of the population was thus produced.

By having a census of ASD SPOs, the researchers identified the techniques used and amount of data available within one portion of AFSC for making official program estimates. Smaller selections of ESD and SAMSO SPOs were selected to verify that the same techniques and data availability identified within ASD were representative of AFSC.

Data Collection

The model of the Air Force major weapon system acquisition process was developed by a detailed review of the available literature, including AF and DOD regulations, manuals, pamphlets, directives, and other publications. The literature review identified the weapon system acquisition process phases, the agencies involved in making cost estimates during the process (the sources of the cost estimates), and the variety of techniques used to make the cost estimates. The literature review was conducted in response to research question number 1.

The model constructed during the literature review was validated using extensive unstructured interviews with individuals from each of the DOD agencies identified in the model. While the unstructured personal interview was the method of choice in this study, it was not always possible to personally meet with each interviewee. The personal interview was therefore supplemental as required with telephone interviews.

Before beginning the data collection effort, an "Interview Schedule" was prepared as a guide for the unstructured personal interviews. A sample of this schedule is presented in Appendix A. The interview schedule consists of a line of sub-questions developed to answer research question number 2. The interview schedule was sufficiently structured to insure coverage of the research question, but not so rigidly structured as to preclude the flexible probing, checking, and cross checking of data. Detailed notes were taken during each interview. Many interviews were also recorded on a small portable tape recorder for later more detailed analysis.

Before conducting the telephone interviews, contact was made with each interviewee to establish the date/time for the formal telephone interview. A copy of the Interview Schedule was sent to each interviewee prior to the actual interview. During the telephone interview detailed notes were taken and expanded immediately after the interview session. Many telephone interviews were also tape recorded for later detailed analysis.

The time available to conduct the telephone interviews was frequently limited. Because of this, it was not always possible to cover the entire Interview Schedule in detail. Therefore, the sections on when estimates are made, amount of data available, and techniques used were stressed in every interview.

These unstructured interviews were designed to ascertain the following information:

1. Name of individual interviewed--all individuals interviewed were practicing estimators, currently involved in the estimating process. As such, they provided expert opinion and data for the study. However, to insure candor, the individuals were offered a guarantee that, if they desired, their names would be held in strict confidence.

2. Organization to which the individual belongs--the organization of the individual was ascertained to demonstrate that the sample included a wide representation of the population.

3. Length of time the individual has been in current position--this data was necessary to establish the expert status of the individual as a practicing estimator representing the views of his organization.

4. Individuals background in estimating--this data was also necessary to establish the expert status of the individuals as a practicing estimator.

5. Details of the estimating techniques the individual uses in any phase of the weapon system acquisition process where the individual makes estimates--this data was necessary to validate the model developed in Chapter II

and insure that the categories developed are accurate.

6. The individual's views concerning the usefulness of the techniques used--this data was used to provide a better insight into the different estimating techniques and to possibly improve the model and the estimating process.

7. The individual's views concerning whether the techniques used are the most appropriate techniques available--this data was used to modify the model, if appropriate, and to provide insight into different ways to possibly improve the estimating process.

Criteria for Research and Comparison

The validation process involved interviewing large numbers of people from organizations that make cost estimates to validate the information obtained from the literature review. It involved the subjective judgement of the researcher, but this judgement was based on detailed analysis of all information available.

The criteria established for this research was that, for the model to be valid, the real world estimating environment would have to match the model 100 per cent of the time for the following:

1. An agency will make an estimate during each of the acquisition phases as specified in the model for that particular agency.

2. The technique actually used by the agency

matches the technique category specified in the model for that agency in that phase of the acquisition process.

Assumptions and Limitations

In developing and validating the model, it will be necessary to accept certain limitations and to make certain assumptions. These limitations and assumptions are considered to be an integral part of the research design.

Assumptions. The following assumptions applied to this research effort:

1. The data obtained from individual estimators through the unstructured interviews was unbiased.
2. The technique categories identified in the model include all techniques available to the estimators.
3. The available techniques are properly categorized.
4. The sample can be considered representative of the population.
5. A census of ASD SPOs and a smaller sample of ESD and SAMSO SPOs was considered representative of the techniques used and amount of data available within all AFSC SPOs for making Official Program Estimates.
6. The amount of data available and the techniques used by the civilian contractors is dictated by the SPO associated with the particular weapon system.

Limitations. The following limitations applied to this research effort:

1. The data collection is limited by the ability of the authors to collect the required data and by the ability and willingness of the data source to provide the required data.

2. A number of interviews had to be conducted by telephone rather than in person due to time and travel limitations.

3. The validity of the study was not reduced because of the sampling technique used in the AFSC SPOs.

4. Only DOD agencies were considered in this research effort. Civilian contractors were considered an uncontrollable factor and were thus eliminated from the population.

CHAPTER IV

ANALYSIS AND SUMMARY OF FINDINGS

Approximately 80 individual estimators from all the organizations/agencies involved in estimating the costs for the acquisition of new AF weapon system were interviewed as part of this study as a validation effort for the model presented in Chapter II. This chapter is an analysis of the interviews by organization/agency. Each organization/agency is looked at in detail to ascertain when they make estimates, the techniques they use and why the estimate is made. A comparison of the literature model and the real world model will be made. The chapter will be concluded with some general impressions which cut across all organizations/agencies. The development of the real world model and the impressions are based upon the interviews conducted. The impressions form the basis for many of the conclusions reached in Chapter V.

The Operational MAJCOMs and the AF CAIG were identified within the course of the data collection as potential sources of cost estimates and were added to the research effort. Data were collected from these organizations using the same methodology outlined in Chapter III for collecting data from the previously identified organizations.

As anticipated in the initial model, the individual estimators in all organizations/agencies visited perceived that the amount of data available for use in generating cost estimates grows in quality and quantity as the weapon system progresses toward turn-over to the using command. They also perceived the data availability to be closely connected to the phase of the acquisition cycle that the program was in and the degree to which the program was defined.

During the conceptual phase, the estimators work primarily with concepts developed to satisfy the ROCs. The data is based upon paper requirements. There is little scope or content to the data, which is considered scarce and hard to obtain. Estimates are based on the "educated guesses" of the engineers and managers associated with the program. As the program moves into the validation phase, the number of different concepts under consideration is narrowed down. The weapon system is further defined, allowing the estimator to make analogies to other programs with more confidence. The amount of data continues to grow in the full scale development phase as the weapon concept is narrowed down to one system and the contractor data from prototype production becomes available. In the production phase, the estimator has a much broader data base to work with. Actual production data becomes available on the weapon system. Also, the Research and Development (R&D) effort on the weapon system is completed and the costs for it are known.

This eliminates estimating the most difficult (high risk) portion of the weapon system acquisition, but in most cases "estimates" are no longer needed as a basis for obtaining funds from Congress since these funds have already been received and committed.

The amount of data available to the cost estimators matches the model for all organizations/agencies for the phases in which they generate cost estimates. The individual cost estimators all reported using the data that they perceived as the best available at the time to generate a cost estimate.

The data growth was the only area of the model that resulted in 100% agreement across all organizations/agencies. The remainder of this chapter will present the data on each organization/agency and is in support of the model presented in figure 4 (page 83).

AFSC and AFLC Required Operational Capability (ROC) Cost Estimates

HQs AFLC and AFSC are tasked to provide preliminary cost estimates for new ROCs. AFLC provides the preliminary cost estimates for ROCs that can be satisfied by modifying the configuration of a current item. AFSC provides the preliminary cost estimate for ROCs requiring a research and/or development effort. Both headquarters' monitor and evaluate the ROC cost estimates generated under their direction (39; 44).

<u>AFLC (ROC) cost estimates</u>. HQ AFLC is tasked to provide preliminary cost estimates on ROCs that can be satisfied by modification to an existing weapon system. This cost estimate is required early in the conceptual phase. The Plans Division (AFLC/XRX) monitors the ROCs and the appropriate Air Logistics Center (ALC) provides all cost estimates on the proposed modification. These cost estimates are called Modification Proposal Analyses (MPA) (39). The data available this early in the acquisition cycle is very limited. There is generally little or no program cost data and only broad, conceptual ideas (possible solutions) to satisfy the ROC. In some cases there may be analogous programs from which partial data is available (40; 41).

The primary technique used to generate the initial cost estimate is that of round table discussions by ALC technicians and logisticians. If any data is available, from the contractor on the original configuration item (weapon system) which is to be modified, it is analyzed and modified as appropriate to fit the proposal (40; 41).

These technicians and logisticians make the cost estimates based on all available data and on their experience with other programs. It is perceived that these cost estimates are rough, best guesses and that the final cost may be entirely different (40; 41).

After the estimate is submitted by the ALC, it can be used for a comparison with other possible solutions or in evaluating program affordability. These cost estimates are not used for specific funding purposes, but only as a basis for trade-off analyses (39).

AFSC (ROC) cost estimates. HQ AFSC is tasked to provide preliminary cost estimates on ROCs requiring a research or development effort. This requirement occurs in the early conceptual phase of the acquisition cycle for the proposed program. The Policy and Programs Division (AFSC/XRX) monitors the ROCs and the Cost Analysis (AFSC/ACCA) and Product Divisions (ASD/ACC, ESD/ACC, SAMSO/ACC, ADTC/ACC) provide support in preparing the cost estimates. These are not the cost estimates used for DSARC I, but merely early rough guesses (44).

There is virtually no program-related cost estimating data available at this point in the acquisition process. The only information available is the statement of an operational requirement/capability that does not presently exist. To solve this lack of data problem, command experts are asked to provide possible technical solutions. For each alternate solution an attempt is made to "develop production support costs and total life cycle cost estimates (to include risk assessment for each alternative) [44]."

These cost estimates are generated using the round table and expert opinion techniques. The cost estimates for each proposed technical solution are made using the same criteria and methodology. This is necessary so that the estimates can be readily compared with each other and a rough cost analysis or trade-off between the proposed solutions made (44).

The HQ AFSC estimators believe that the cost estimates generated this early in the acquisition process are "for concepts only and are not intended to represent exact hardware cost [44]." These cost estimates are not used for specific funding purposes. They are used for comparison of technical solutions only and the "estimates" are rightfully ignored for funding purposes by the field (44).

Summary. HQs AFSC and AFLC match the model completely. They evaluate cost estimates of concepts for satisfying ROCs in the early part of the conceptual phase. There is very little data available on the new concepts at this point in the acquisition process, which necessitates the use of parametric cost estimating techniques. These cost estimates are for comparison of alternatives only and are not used as official program estimates by the DSARC or for future funding purposes (39; 44).

Operational MAJCOMs

The operational MAJCOMs (ADCOM, MAC, SAC and TAC) do not make estimates on the ROCs they generate (54; 55; 56; 57). Once the need or requirement for a new weapon system to meet an operational mission is generated, the ROC is forwarded to AFLC and/or AFSC. AFLC/AFSC provide the concepts or solutions which will be used to meet the requirements, as well as the initial cost estimate for the ROC. The operational MAJCOMs rely almost totally upon AFLC/AFSC generated cost estimates for new weapon systems (54; 55; 56; 57).

The operational MAJCOMs do not make "system acquisition" cost estimates on the new weapon system as it progresses from a ROC to an operational system. The MAJCOMs have no expertise in the area of Research and Development (R&D) cost estimating. They are primarily concerned with the operations and support (O&S) or operations and maintenance (O&M) costs rather than the R&D costs (54; 55; 56; 57).

The operational MAJCOMs become involved in the acquisition process when the SPOs recommend requirements tradeoffs. The primary emphasis of operational units in this area is to limit the impact of requirements tradeoffs provided by the SPOs which result from changes in technology and may reduce the capability of the new system. Once again though, the MAJCOMs do not attempt to make a system cost estimate. Instead, they serve as a source of information on O&M or O&S requirements and costs for the weapon system resulting from the system configuration which would result from the alternatives proposed (54; 55; 56; 57).

System Program Offices

Cost estimates are generated by System Program Offices of three different AFSC organizations. Aeronautical Systems Division (ASD) makes estimates on aeronautical systems--aircraft and air launched weapon systems. Electronics Systems Division (ESD) makes cost estimates on all major electronic weapon systems. Space and Missile Systems Organization (SAMSO) makes estimates on ballistic missile and space systems.

Aeronautical Systems Division. ASD SPOs generate cost estimates in all four phases of the weapon system acquisition cycle. Within ASD, the Directorate of Cost Analysis, Advanced Systems Division (ASD/ACCX) is responsible for generating the cost estimates in the conceptual phase. The SPOs, which are formed toward the end of the conceptual phase, use the estimates generated by ASD/ACCX as their own estimate for that phase. The SPO personnel generate their own estimates in the remaining phases. "ASD/ACCX does the initial phase estimating [47]." Therefore, ASD/ACCX is considered by ASD personnel to be the SPO for the major portion of the conceptual phase. They work on pre-ROC studies and conduct studies to meet the ROC after it is developed (47).

The amount of data available for use by the estimators influenced the type of technique used to a great extent. Personnel from one SPO emphasized this, claiming "The technique used is driven by the amount and type of data available [47]." The ASD SPO estimators use parametric estimating techniques in the conceptual and validation phases. The RCA PRICE model is used for estimating electronic equipment. CERs, expert opinion, and analogies are relied upon quite heavily for generating cost estimates in both of these phases. An attempt is made to correlate design parameters to historical cost data from other programs and arrive at the estimated cost of the new weapon system. In the full scale development phase, the estimators use some parametric techniques, but begin to rely on engineering techniques. They are able to use detailed engineering, statistical (grass roots), marginal analysis and trend analysis techniques. Prototype weapon systems have been developed and produced, yeilding a much greater data base to work with. The estimators also have the work break down packages from the Cost/Schedule Control Systems Criteria (C/SCSC) available for the weapon system they are working on. This added data base allows the estimator to use the engineering techniques. In the production phase, actual production data is available. Historical standard time/cost by task and historical trends are used to generate the cost estimates during this phase (47).

Cost estimates are generated by the ASD SPOs for a variety of reasons, the primary ones being for program advocacy to the AFSARC and DSARC and for budget preparation. Cost estimates are also used for program control and adjustment, "what if" contingency reviews, and in support of source selection and contract negotiations. In the conceptual and validation phases, the cost estimates are used in making comparisons between the different weapon systems under consideration. The cost estimates give the decision makers at the Air Staff and DOD a gross idea of the costs involved to achieve a certain capability (47).

In summary, the ASD SPOs validate the model in all areas except technique used. The ASD SPOs make cost estimates in the conceptual, validation, full scale development, and production phases of the weapon system acquisition cycle. The amount of data available for generating cost estimates grows from very little (vague) to extensive, production data (historical). The quality and quantity of data grows as the weapon system progresses through the cycle while the risk and the time over which estimates are required to be valid decreases. The SPOs make estimates for two major reasons--program advocacy and budget generation. In the area of techniques used, the ASD SPOs use parametric estimating techniques to generate cost estimates in the conceptual and validation phases. They use research and development and engineering techniques in the full scale development phase, and standards techniques in the production phase. The type of technique used is dependent upon the amount of data available. The individual estimator choses which technique he will use based upon his interpretation of the amount of data available (47).

Electronics Systems Division. The ESD SPOs make cost estimates in the four phases of the major weapon systems acquisition process (conceptual, validation, full scale development and production). The only case where the SPO might not make an estimate is during the conceptual phase, and then only if that SPO had not yet been formed. From the time of their conception until their dissolution, the ESD SPOs maintain a current cost estimate for their program. This estimate is updated throughout the acquisition cycle as new data becomes available and as changes are made to the program. In the production phase the basic cost estimate is analyzed to get estimates of time, number and cost changes (50).

All ESD SPO estimators perceive that the techniques used in the different phases of the acquisition cycle for making cost estimates are directly related to the amount and type of data available. In the conceptual phase, the RCA PRICE model and/or a round table type technique are used to make cost estimates. The RCA PRICE model uses both objectively and subjectively based data. The round table technique consists of cost analysts and SPO engineers working together in conference to develop the cost estimate. During the validation phase, price lists (where available) and contractor estimates (adjusted as necessary by the SPO) are used. Parametric techniques are also used as a check on the contractor estimates. In the full scale development phase contractor data (again adjusted as appropriate) and parametric techniques are used. Finally, in the production phase the contractor estimates, with only minor adjustments, are used. The ESD SPO estimators believe that the contractors use parametric techniques and price lists in the validation phase, technical/engineering techniques in the full scale development phase and standards (gained from actual production) techniques in the production phase. The SPO makes a check for reasonableness of the contractors estimate. This check is made by the technical/engineering analysis personnel using parametric techniques. The most popular parametric technique used is the RCA PRICE model (50).

Cost estimates are made yearly for the POM and budgetary reasons. They are also made at each of the DSARC decision points: at DSARC I to "see if we should go this way and if it is cost effective [50]"; at DSARC II to decide between alternatives and for resource allocation; and at DSARC III as a last chance to say no on the project or decide how many to buy. In the production phase cost estimates are made to check costs of numbers, time/schedule and technical changes, or to estimate what changes are necessary if the budget is adjusted. Another purpose for making a cost estimate in any of the phases of the acquisition cycle is for new contracts. All of the estimates made are perceived by the ESD SPO estimators as being used throughout the chain of command (SPO, HQ AFSC, HQ AF and OSD) for the purposes mentioned earlier in this paragraph (50).

In summary, the ESD SPOs match the model in all parts with the exception of the techniques used to make an estimate. They rely heavily on the estimates made by the contractor once he has been identified. In this sense, they only adjust an already completed cost estimate. This adjustment is based on a parametric evaluation of the contractor estimate and on past experience with the contractor. In the conceptual phase they match the model by using the RCA PRICE model, which is considered a parametric technique. In the validation and full scale development phases they do not match the model because they use parametric techniques to check the contractors estimate. In the production phase they again adjust the contractors estimate as necessary. The type of data available in the different phases does match the model by starting as vague in the conceptual phase and building to historical in the production phase. The purposes of the estimates in the different phases also matches the model. Budgeting and official SPO estimates are required in the conceptual, validation and full scale development phases, while cost analysis estimates are needed in the production phase (50).

Space and Missile Systems Organization. Cost estimating for new major weapon systems within the SAMSO SPOs follows the sequence of the Weapon System Acquisition Process. Many of the program offices contacted reported that their programs were already into the production phase. In some cases, data on the estimating techniques used and the amount of data available to make estimates could not be reconstructed. However, cost estimates are generated following the requirements and policies of the weapon system acquisition process--in the conceptual, validation, full scale development and production phases (52).

The SAMSO SPOs use models to generate their cost estimates in all phases. Many SPOs do not have cost estimating personnel assigned to them and the Directorate of the Comptroller is relatively small--10 people assigned (51; 52). In most SPOs the project officers and/or engineers look at how the program is defined, what the schedule is for the system, and attempt to estimate what equipment--e.g., electronics, propulsion, sensor, etc.--will be needed to meet the requirements of the weapon system. They also attempt to obtain data from the contractor, if possible. Using this data, the project officers make an estimate of what the system will cost.

This technique is referred to at SAMSO as an Engineering Cost Estimate. It is developed using, at different times, techniques from all four catagories of estimating techniques identified in the model (52).

Concurrent with this effort, the SPO may request the Comptroller (SAMSO/ACCE) to support them by conducting an Independent Cost Estimate (ICE).[1] The ICE is generated using a parametric cost estimating model. SAMSO/ACCE has developed two models that are frequently used--the SAMSO Unmanned Spacecraft Cost Model and Schedule Program Allocation of Resource and Cost (SPARC). The SAMSO Unmanned Spacecraft Cost Model is used primarily with satillite systems and the SPARC model is used for launch vehicles or boosters. The SPO may also have the Aerospace Corporation (a captive contractor who provides engineering and technical support to SAMSO) generate a cost estimate. Aerospace Corporation also uses a parametric cost estimating model to generate the cost estimate. The primary difference between these models is that the SAMSO/ACCE models are based on subsystem level data while the Aerospace Corporation model is based on component level data. In either case, the SPO must provide the data necessary to drive the model used (52).

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[1]The ICE should not be confused with an ICA, which is also performed by SAMSO/ACCE. The ICE is prepared specifically for the SPO by SAMSO/ACCE personnel who will not be involved with the ICA. The ICA is used to check the reasonableness of the SPO estimate. Independence between the SPO estimate (ACCE generated ICE) and the ICA is preserved (52).

The SAMSO Unmanned Spacecraft Cost Model was developed between 1966 and 1969, and was revised in 1971, 1972, 1973, 1975, and again in 1977. The model uses data on seven subsystems--structure, thermal control, propulsion, communications, electrical power supply, telemetry tracking and command, and the attitude control system. The model uses the weight, size (volume) and number of units required for each of the subsystems. CERs are available for each of the subsystems to make the transition from historical spacecraft costs to conceptual spacecraft cost estimates.[2] The SPARC model was developed in 1968 for use with launch vehicles and ICBMs. It was revised in 1971 and is currently under revision for use on the MX ICBM (51; 52).

Once the SPOs have the engineer's cost estimate and the ICE (from either or both SAMSO/ACCE or Aerospace Corporation), they go through what is called the normalization techniques. This technique consists of updating or normalizing the ICE by the use of complexity factors subjectively derived by the SPO engineers for their particular program. SAMSO/ACCE also provides normalized CERs for use in their model. The different estimates are

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[2]For further information on the SAMSO Unmanned Spacecraft Cost Model and the cost estimating relationships and normalization factors, the reader is directed to the following SAMSO documents: SAMSO Unmanned Spacecraft Cost Model, third Edition, July 1975 (SAMSO TR-75-229) and SAMSO Unmanned Spacecraft Cost Model Updated Cost Estimating Relationships and Normalization Factors (An Interim Report) dated Jan. 77.

then examined and compared. Any differences found are resolved between the project officers and the individuals performing the ICE. In this manner, the official program estimate becomes a composite of the engineer's cost estimate and the ICE (52).

In the conceptual and validation phases, the project officer/engineer relies very heavily on parametric techniques in generating the cost estimate. In the full scale development phase, contractor data becomes available for the first time, facilitating the use of techniques other than parametrics. The primary reason the SAMSO SPOs rely upon the parametric cost models in the conceptual and validation phases is because the weapon systems are frequently one-of-a-kind programs that are pushing the state-of-the-art in technology. Little useable data is available from previous programs. The data used to drive the models ranges from estimated engineering data (using analogies to other programs whenever possible) in the conceptual and validation phases to actual production data in the production phase. Therefore, SAMSO/ACCE developed the models presented above to help use the data points from previous programs. These models are under continual review and are updated frequently (52).

The SAMSO SPOs generate cost estimates for a variety of reasons. Two main reasons are the official program estimate used for program advocacy at the AFSARC and DSARC and budget estimates. Cost estimates are also made for contingency planning purposes and in response to "what if" questions from higher headquarters. SPO cost estimates are used in planning, controlling, budgeting and decision making at all echelons of command authority from the SPO director to the Secretary of Defense, Congress and the President (52).

In summary, the SAMSO SPOs do validate the model, as developed in Chapter II, in all areas except for technique used. Official SPO estimates are made in each phase of the acquisition cycle--conceptual, validation, full scale development and production. The data available for making cost estimates corresponds to the amount of data available that was predicted for each phase. Data availability grows from little or no useful data (vague) to hard, actual production data (historical) as the weapon system is conceived, defined, tested and produced for operational use. The technique used to generate the cost estimate progresses from parametric techniques in the conceptual and validation phases to research and development and/or engineering techniques in the full scale development phase to a standards technique in the production phase (52).

Major Command ICAs

Independent Cost Estimates are generated under the direction of the Comptroller, HQ AFLC and HQ AFSC. The HQ AFLC Comptroller is responsible for the generation of ICAs on major AF weapon system programs that are under the control of AFLC. These are programs that involve major modifications to existing weapon systems. The HQ AFSC Comptroller is responsible for generating ICAs on major weapon system programs that are under the control of AFSC, i.e., new weapon system acquisitions. The ICEs generated by these organizations are used within the Independent Cost Analysis program which supports the AFSARC and DSARC programs (38; 43).

HQ AFLC ICA. The Comptroller, HQ AFLC, makes at least one cost estimate in each of the first three phases of the acquisition cycle. The ICAs are accomplished just prior to the DSARC at the end of the conceptual, validation and full scale development phases (38).

In the conceptual phase, the estimators use general performance parameters specified for the modification. The estimators also use data from programs with similar performance parameters. In the validation phase the same type of data is used. However, the data is better defined and in more detail. Design specifications and engineering "build-up" data (specifications and/or costs for subassemblies) are used in the full scale development phase (38).

The AFLC Comptroller cost estimators indicated that " . . . techniques used are limited only by the available data [38]." The techniques that are used in the conceptual phase are analogies and CERs. In the validation phase analogies and CERs are again used, with the addition of build-up/grass roots and statistical techniques when possible. The estimators use models such as the MOD Metric Model and the Logistics Support Cost Model in the full scale development phase. These models are used, in conjunction with the parametric and grass roots techniques, if the proper data is available. The individual estimator choses the technique which he perceives as best suited for use with the available data (38).

The Comptroller, HQ AFLC, makes cost estimates in support of the ICA program. The ICA is generated to check the validity and reasonableness of the SPO estimate. The ICA is reviewed by the AF CAIG and OSD CAIG in support for the AFSARC and DSARC programs (38).

HQ AFSC ICA. AFSC Independent Cost Estimates are generated by the Directorate of the Comptroller, Aeronautical Systems Division (ASD), Electronics Systems Division (ESD), and Space and Missile Systems Organization (SAMSO). These Independent Cost Estimates are used within the AFSC Independent Cost Analysis (ICA) program. Each organization has developed and implemented an ICA program to support AFSC ICA requirements (43; 46; 49; 51). These organization ICA programs are:

1. Aeronautical Systems Division--ASD, as part of its ICA program, prepares an Independent Cost Estimate (ICE) for each DSARC review of a program controlled by an ASD SPO.

An ICA is prepared at the end of the conceptual, validation and full scale development phases. The testing required in the full scale development phase may not be completed when the DSARC meets. To prevent a time gap between the development and production of the prototype weapon system and the beginning of production of the operational weapon system, the DSARC meets to decide if a limited production should begin while testing continues. The lead time between the end of prototype production and operational production can run as long as $1\frac{1}{2}$ years. Delaying production until all testing is completed could severely hamper production schedules and raise production costs. Therefore, two estimates are frequently made for the full scale development phase (DSARC III A and DSARC III B) (46).

The techniques used to generate the cost estimate are closely related to the amount of data available. The ASD ICA program uses parametric estimating techniques for the conceptual and validation phase estimates. Cost models, analogies, CERs and regression analysis are examples of the parametric techniques used in these phases. In the full scale development phase, the ASD ICA program uses a "bottoms up" technique. This technique is a combination of the parametric techniques used earlier and a grass roots approach using the work breakdown structure of the Cost/Schedule Control Systems Criteris (C/SCSC). This technique is also used in the validation phase whenever possible (46).

The purpose of the estimate generated by the Directorate of the Comptroller, ASD, is to provide a check of the methodology and reasonableness of the System Program Office (SPO) cost estimate. It provides the Air Staff, AF CAIG, and OSD CAIG with an independent view of the cost of the proposed weapon system. The ICA estimate is reviewed at the AFSARC and the DSARC (46).

2. Electronics Systems Division--ESD has an Independent Cost Analysis program similiar to the ASD program. Cost estimates are made at the same three points in the Weapon System Acquisition Process--conceptual, validation, and full scale development phases. ESD also makes two ICAs during the full scale development phase when the weapon system involved has a long lead time between prototype development, production and testing and operational system production and deployment. The second estimate (for DSARC III B) is considered by ESD/ACCE personnel to be an update of the estimate made for DSARC III A rather than a completely new estimate (49).

ESD makes extensive use of parametric cost estimating techniques in all ICA estimates. Parametric techniques (analogies to other systems primarily) are used to estimate the cost of hardware and software configurations that will be required in the weapon system. The List Price or Catalogue Price technique is then used to price out the electronic components. The electronics used in radar and communications weapon systems are basically off-the-shelf items, which lend themselves to the use of the list price technique. The RCA PRICE model is used, in conjunction with the list price technique, to generate the cost estimate. In the full scale development phase, the grass roots or detailed engineering technique is frequently used. A parametric technique is also used to generate a backup estimate and to give credence to the grass roots/detailed estimate. ESD estimators frequently attempt to estimate the costs of a weapon system using two different methods for comparative purposes (49).

The ESD ICA is used by the Air Staff, AF CAIG (AFSARC), and OSD CAIG (DSARC) as a confirmation check on the methodology and accuracy of the official SPO estimate. It is also used to verify the SPO estimates' validity and reasonableness (49).

3. Space and Missile Systems Organization--The SAMSO ICA program is very similiar to the programs developed at ASD and ESD. SAMSO/ACCE also makes cost estimates for each of the DSARC reviews at the end of the conceptual, validation and full scale development phases (51).

SAMSO estimators are hampered by the lack of an extensive data base, more so than their ASD and ESD counterparts. A common complaint was, " . . . data on parameters other than weight and power weren't collected [51]." A second reason is that not as many space systems have been developed and produced as have aeronautical or radar/communications systems. In addition, space systems are not produced and deployed in large numbers. Each space system is substantially different from any other space system. SAMSO cost estimators are able to use standard, actual costs for launch vehicles. The Titan launch vehicle is used to launch most spacecraft systems and the costs are well known from historical data. This reduces the requirement for new estimates of this rather costly portion of the overall weapon system (51).

Parametric estimating techniques are used in all three phases by the SAMSO estimators. Extensive use is made of cost models which have been developed by SAMSO/ACCE. The particular model used is dependent upon the type of program or portion of the program being estimated (51). The SAMSO Unmanned Spacecraft Cost Model is used on all spacecraft and communications programs. Estimating the cost of sensors for the different spacecraft is very difficult because of a lack of experience in the area and the wide range of sensors used. Analogies use of data from other programs, and the use of the ACCE models represent attempts to overcome these problems. The RCA PRICE model and catalogue data are used to estimate the costs of the ground station portion of the weapon systems and, as stated previously, actual production costs are used to estimate the launch vehicle portion of the weapon system. As better and more factual data becomes available in the full scale development phase of the program, it is used to drive the model. The more factual data replaces the earlier estimated data which was used in the model (51).

The SAMSO ICA estimate is used to check the validity and reasonableness of the official SPO estimates, the methodology used, and the accuracy achieved. It provides the Air Staff, AF CAIG, and OSD CAIG with an independent view of what the program costs for the weapon system is estimated to be. The ICA estimate is used in the AFSARC and DSARC reviews (51).

Summary. The AFLC and AFSC (ASD, ESD, and SAMSO) ICA programs all match the model in the areas of when cost estimates are made, the amount of information available for making estimates, and the type/purpose of cost estimates made. The SAMSO program conforms to the model in the area of techniques used. However, the ICA programs at HQ AFLC, ASD and ESD, do not. These organizations use grass roots/detailed engineering (Research and Development Techniques) techniques in the validation and full scale development phases whenever possible, as well as parametric techniques, to generate their ICA estimates (38; 43; 46; 49; 51). The rationale behind this difference is that to get the best (most accurate) estimates, the available data (whether parametric CER's or engineering actuals) should be used.

Justification for this rationale comes from AF Reg 173-11 paragraph 4.a (35).

AF CAIG

The AF CAIG was not included in the model of the Air Force Cost Estimating Process within the Air Force Weapon System Acquisition Process developed in the literature review. It was identified as a potential source of cost estimates during the data collection phase of this research effort, and was therefore investigated as part of the research effort. HQ Operating Instruction 173-3, dated 26 June, 1974 " . . . establishes the AIR Force CAIG with membership and responsibilities parallel to those of the OSD CAIG [58:1]." The primary responsibility of the AF CAIG is to " . . . act as an advisory body to the Secretary of the Air Force for Financial Management and the Comptroller of the Air Force on all matters related to weapon systems costs to be presented to the OSD CAIG [58:1]." The AF CAIG provides the Assistant Secretary of the Air Force for Financial Management (SAF/FM) with cost issue summaries and an evaluation and review of ICAs prior to their submission to the OSD CAIG. The SAF/FM uses the AF CAIG report at the meeting of the AF System Acquisition Review Council (AFSARC), a review body similiar in composition, responsibilities and operation to the DSARC (see page 12) (30:2).

Additional AF CAIG responsibilities include:

1. Assessing and making recommendations concerning

all cost objectives contained in Decision Coordinating Papers (DCPs) and Program Decision Memoranda (PDMs) before they are submitted to OSD.

2. Accomplishing cost studies and other cost related tasks as requested by Secretary of the Air Force or Chief of Staff of the Air Force.

3. Conducting direct efforts which will improve the cost estimating capability of the Air Force and reporting periodically to the SAF/FM and Comptroller concerning these efforts (58:11).

HQ USAF/ACM is tasked to prepare a proposed AF CAIG report which includes a summary of the cost issues that will be addressed by the AF CAIG. This report and the command ICA are reviewed and evaluated prior to the submission of the ICA to the OSD CAIG. The proposed report functions as the basis of the final AF CAIG report, which incorporates the comments and recommendations of the AF CAIG, summarizes all cost issues, and provide the AF CAIG's overall evaluation of the command ICA (58:1).

In depth interviews with members of the AF CAIG revealed that the AF CAIG accomplishes a formal review and evaluation of all command ICAs prior to the submission of the ICA to the OSD CAIG. In conjunction with this review and evaluation, the AF Comptroller (ACM) may make a cost estimate to check the validity and reasonableness of the command ICA and SPO estimates. The review and evaluation of Command ICAs take place in the conceptual, validation and full scale development phases of its weapon system acquisition cycle. The AF CAIG also makes cost estimates and/or reviews and evaluations for DCPs and PDMs. They also make cost estimates in response to congressional inquires. These activities can and do occur at any time during the weapon system acquisition cycle (37).

AF CAIG estimators pointed out that the amount and type of data available for their use limited the choice of techniques they can use. They employ models, CERs, lab studies, regression analysis, parametrics, and bottoms up or grass roots techniques. In most cases, however, the estimators are limited to the use of parametric techniques. They attempt to replace the analogous data with actual data as it becomes available (37).

The individual estimators also felt that they were restricted to the use of parametric techniques because of time limitations. The review and evaluation of the command ICA and the generation of a new cost estimate, when required, must normally be accomplished within five (5) working days between the receipt of the ICA and the preparation of the proposed report. This time factor prevents the estimators from using more detailed techniques, such as bottoms up or grass roots, which require more time to complete than is available (37).

Another limiting factor is the number of personnel assigned to perform the review and analysis function. Presently only six people are assigned as cost analysts and Program Cost Monitors (PCMs). These people must perform the cost analyses on the ICAs and prepare new estimates if the facts warrant. They also perform the review and evaluation for other cost estimates outside the DSARC process that the AF CAIG requires (37).

The primary reason for the AF CAIG is to support the SAF/FM with information for making program decisions. The AF CAIG looks for agreements/disagreements between the SPO estimate and the command ICA. If there is a major disagreement between these estimates, the AF CAIG comments on the reasons for the differences and makes recommendations to the SAF/FM. The SAF/FM makes the decision on which estimate, the command ICA or the AF CAIG estimate, to forward to the OSD CAIG. Only one estimate will be forwarded. If there are no major disagreements, the command ICA estimate will be forwarded to the SAF/FM (37).

The AF CAIG also do their own review and evaluation, and make cost assessments or recommendations on DCPs, PDMs, or in answer to congressional inquires. These cost estimates and/or assessments and recommendations are used for planning in all phases of the weapon system acquisition cycle by the SAF/FM, members of the Air Staff, and the Program Element Monitor (37).

In summary, the AF CAIG makes cost estimates and/or reviews and evaluations of command ICAs in the first three phases of the weapon system acquisition cycle (conceptual, validation and full scale development). They also make cost estimates, assessments and recommendations based on estimates generated by other organizations in these three phases and in the production phase. The data used to make these reviews and evaluations (and new cost estimates when necessary) increases in quality and quantity as the weapon system progresses through the acquisition cycle. The AF CAIG is limited to the use of parametric cost estimating techniques because of the amount and type of data available, the amount of time available to conduct the review and limited number of personnel assigned. The reports generated by the AF CAIG, their reviews and evaluation of the ICAs and new cost estimate, if required, are used by the SAF/FM to make program decisions prior to submission of the ICA and SPO estimate to the OSD CAIG. The findings of the AF CAIG are used by the OSD CAIG in making their recommendations to the DSARC. The assessments and recommendations made by the AF CAIG separate from the DSARC process are used for planning and budgeting by the SAF/FM, members of the Air Staff, and Program Element Monitors. They are also used to respond to congressional inquires (37).

OSD CAIG

The OSD CAIG reviews the ICA and SPO estimates prior to each DSARC review. It provides the DSARC with an assessment of and/or a recommendation on all cost objectives. In most instances, the OSD CAIG does not provide an estimate of its own. If in their opinion a major item has been misinterpreted or left out of a cost estimate, however, they will make their own estimate and forward it to the DSARC along with the ICA and SPO estimates. The OSD CAIG, in fulfilling its responsibility to "accomplish other tasks and specific studies as requested by the DSARC principles [32]" also provides cost estimates to answer questions from the DSARC on such issues as cost growth (32).

The techniques available to the OSD CAIG are limited by time and manpower availability. The OSD CAIG normally has only nine days in which to review the documentation provided to them. In this time frame they must analyze the data, make a cost estimate (if required) and provide their report to the DSARC. Two individuals assigned to the OSD CAIG are primarily responsible for the cost analyses of all major AF weapon system acquisitions. Therefore, the techniques used are parametric in all phases (32).

The cost estimates and/or reviews of the ICA and SPO cost estimates made by the OSD CAIG are provided to the DSARC in the form of a report. This report is used by the DSARC in making recommendations on resource allocation; that is, whether or not the weapon system should proceed to the next phase, be discontinued, or continue in the current phase. The DSARC recommendations, in the form of a report, are used for planning and budgeting by both the DOD and the Air Force. The OSD CAIG report is also sent to the AF CAIG, where the cost explanation and analysis can be used to improve the future cost estimates (32).

In summary, the OSD CAIG validates the model. They evaluate and review the SPO and independent cost estimates. They also make an actual cost estimate when requested to do so or when they believe one is required. The OSD CAIG provides the review and/or estimate just prior to the DSARC reviews. The most current data available is used in the analysis of the SPO and ICA estimates. This data was perceived to grow in quantity and quality as the weapon system progresses through the acquisition cycle. The data grows from very little in the conceptual phase to some cost actuals in the full scale development phase (32).

It should be noted that personnel from the OSD CAIG have found one "discrepency" in our description of them on page 15 of this thesis. "The OSD CAIG does not resolve differences between the ICA and SPO estimates. They only <u>explain</u> the differences [32]." With this in mind, they believe that they have no advocacy role to play and thereby perceive their estimates and evaluations as more objective than anyone else's. They also believe that this objectiveness is the reason their estimate changes less than the SPO and ICA estimates during the acquisition cycle (32). Their data indicates that the SPO and ICA estimates tend to approach the less optimistic OSD CAIG estimates as a weapon system progresses through its weapon system acquisition cycle.

Research Questions Answered

> Research question 1. What model of the cost estimating process for new major Air Force weapon systems can be developed that depicts:
>
> a. the organization/agency providing each cost estimate,
>
> b. the purpose for which each cost estimate is developed,
>
> c. the point in the acquisition process where these estimates are made, and
>
> d. the techniques which are appropriate to each organization/agency in producing their estimate, considering the information available at the point when the estimate is needed?

A model to answer research question 1 was originally developed in Chapter II based on management theory and a review of the available literature. It is presented in figure 2 (pages 37-38). During the course of the field interviews to validate the model and answer research question 2, the AF CAIG was identified as a source of cost estimates. An "Updated Model of the Air Force Cost Estimating Process Within the Air Force Weapon System Acquisition Process" is presented in figure 3. This updated model includes the AF CAIG and identifies its contribution to the AF cost estimating process.

> Research question 2. If such a model can be developed, can it be validated to demonstrate that it realistically reflects the "real world" estimating environment of the agencies concerned with the acquisition of new major Air Force weapon systems?

Phase	Agency Making Estimate	Type of Estimate Made (Purpose)	Technique Used to Make Estimate	Type of Information Available
Conceptual	AFSC/AFLC	ROC Evaluation	Parametric	Vague
	Contractor*	Estimate from Studies & Cost Proposals	Parametric	Vague
	SPO*	Budget Estimate & Official Program Estimate	Parametric	Vague
	ICA	ICE	Parametric	Vague
	AF CAIG	Evaluation	Parametric	Vague
	OSD CAIG	Evaluation	Parametric	Vague
DSARC I - Program Decision				
Validation	Contractor*	Cost Proposal & Budget Estimates	R & D	Limited
	SPO*	Budget Estimate & Official Program Estimate	R & D	Limited
	ICA	ICE	Parametric	Limited
	AF CAIG	Evaluation	Parametric	Limited
	OSD CAIG	Evaluation	Parametric	Limited
DSARC II - Ratification Decision				

Figure 3

Updated Model of the Air Force Cost Estimating Process Within the Air Force Weapon System Acquisition Process

AD-A044 101 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCHO--ETC F/G 14/1
THE AIR FORCE COST ESTIMATING PROCESS: THE AGENCIES INVOLVED AN--ETC(U)
JUN 77 E M LEWIS, E D PEARSON

UNCLASSIFIED AFIT-LSSR-5-77A NL

2 OF 2
AD
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END
DATE
FILMED
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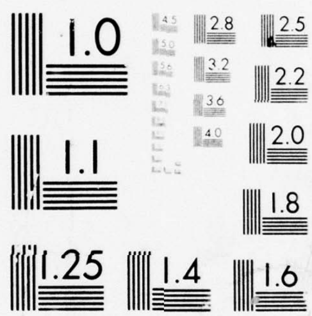
1.0
4.5
5.0
5.6
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

Phase	Agency Making Estimate	Type of Estimate Made (Purpose)	Technique Used to Make Estimate	Type of Information Available
Full-Scale Development	Contractor*	Budget Estimates	Engineering	Detailed
	SPO*	Budget Estimate & Official Program Estimate	Engineering	Detailed
	ICA	ICE	Parametric	Detailed
	AF CAIG	Evaluation	Parametric	Detailed
	OSD CAIG	Evaluation	Parametric	Detailed
DSARC III - Production Decision				
Production	Contractor**	Cost Reporting	Standards	Historical
	SPO**	Cost Analysis	Standards	Historical

*The contractor & SPO can make more than one estimate during each phase. An estimate is made and revised until time of presentation to the DSARC for a decision.

**The SPO & Contractor personnel make continual on-going cost estimates throughout the production phase.

Figure 3 (continued)

Extensive field interviews with cost estimators from each organization/agency identified in the literature review were conducted to answer research question 2. The results of these interviews were analyzed above and a new model was developed to reflect what actually happens in the process of estimating the cost of a major weapon system (see figure 4). The major differences found between the model based on the literature review (figure 3) and the real world model (figure 4) are described below:

1. The techniques used by the System Program Offices do not progress from Parametric (conceptual phase) to Research and Development (validation phase), Engineering (full scale development phase), and Standards (production phase) as predicted by the literature model. Instead, the SPOs use Parametric techniques in both the conceptual and validation phases. The data increases from vague to limited during progress through these phases, but is still apparently not sufficiently detailed or reliable to support the use of techniques more sophisticated than those in the Parametric category.

2. The techniques used to develop the ICA in the validation and full scale development phases are also different in the two models. The ICA estimators use Parametric techniques in all three phases (conceptual, validation and full scale development). When possible, they also attempt to use Research and Development techniques in

Phase	Agency Making Estimate	Type of Estimate Made (Purpose)	Technique Used to Make Estimate	Type of Information Available
Conceptual	AFSC/AFLC	ROC Evaluation	Parametric	Vague
	Contractor*	Estimate from Studies & Cost Proposals	Parametric	Vague
	SPO*	Budget Estimate & Official Program Estimate	Parametric	Vague
	ICA	ICE	Parametric	Vague
	AF CAIG	Evaluation	Parametric	Vague
	OSD CAIG	Evaluation	Parametric	Vague
		DSARC I - Program Decision		
Validation	Contractor*	Cost Proposal & Budget Estimates	R & D	Limited
	SPO*	Budget Estimate & Official Program Estimate	Parametric	Limited
	ICA	ICE	Parametric/ R & D***	Limited
	AF CAIG	Evaluation	Parametric	Limited
	OSD CAIG	Evaluation	Parametric	Limited
		DSARC II - Ratification Decision		

Figure 4

Real World Model of the Air Force Cost Estimating Process Within the Air Force Weapon System Acquisition Process

Phase	Agency Making Estimate	Type of Estimate Made (Purpose)	Technique Used to Make Estimate	Type of Information Available
Full-Scale Development	Contractor*	Budget Estimate	Engineering	Detailed
	SPO*	Budget Estimate & Official Program Estimate	R & D/ Engineering***	Detailed
	ICA	ICE	Parametric/ R & D***	Detailed
	AF CAIG	Evaluation	Parametric	Detailed
	OSD CAIG	Evalustion	Parametric	Detailed
		DSARC III - Production Decision****		
Production	Contractor**	Cost Reporting	Standards	Historical
	SPO**	Cost Analysis	Standards	Historical

*The contractor & SPO can make more than one estimate during each phase. An estimate is made and revised until time of presentation to the DSARC for a decision.

**The SPO & Contractor personnel make continual on-going cost estimates throughout the production phase.

***Techniques actually used will vary from program to program and depend upon the type/amount of data actually available at the time the estimate is made.

****Following DSARC III the AF CAIG and OSD CAIG monitor the cost estimate and respond to inquiries concerning program costs/estimates.

Figure 4 (continued)

the validation and full scale development phases. When the Research and Development techniques are used, they are combined with Parametric techniques. The data available increases in both quantity and detail from one phase to the next in all programs. However, it is not always sufficiently developed or available to allow the use of Research and Development estimating techniques. Aeronautical and electronic weapon systems are developed frequently enough that a better historical data base exists from which to predict costs (41). This accounts for the use of Research Development techniques in ICAs generated for these programs. In all cases, Parametric techniques are used in combination with the Research and Development techniques.

<u>General Impressions</u>

While conducting interviews of cost estimators representing all estimating agencies from the SPOs up to and including the OSD CAIG, it was impossible not to derive some general impressions of the cost estimating process. These observations are summarized below:

1. DOD organizations/agencies identify the need for new weapon systems, define the type of system required to fill the need, and defind the system and its funding before Congress. It would be unrealistic to expect DOD agencies to develop weapon system cost estimates in any but the most favorable light possible. The SPO acts as the official program advocate. As such, their estimates tend to be

optimistic is an attempt to sell the program to AFLC/AFSC, the Air Staff, DOD, and eventually to Congress (47; 50; 52). The ICA estimates are used to check the reasonableness of the SPO estimate. The ICA estimate is generally relatively close to the SPO estimate. This is to be expected since both estimates are generated from the same data base (38; 43; 46; 49; 51). The AF and OSD CAIGs normally only compare the SPO estimate with the ICA estimate to insure that no major discrepancies or differences occur that cannot be explained. The CAIGs also check to insure that the methodologies employed by the SPO and ICA estimators are adequate and appropriate (32; 37). In fact, our information indicates that the SPO, AFLC/AFSC ICA, and the AF and OSD CAIGs all act in varying degrees as program advocates in the majority of weapon systems acquisition cases. The tendency is to present the cost estimates for weapon systems in a favorable/optimistic light which allows the program to continue through eventual acquisition to an operational status. This viewpoint is supported in the literature also. J. Ronald Fox, a former Assistant Secretary of the Army, in his book, Arming America: How the U. S. Buys Weapons, expresses the thought that all levels of management within the DOD attempt to provide overly optimistic estimates to decision makers (10:159-164).

2. The organizations apparently have few or no mechanisms established which would motivate cost estimators

to develop estimates that accurately reflect the eventual total cost of the weapon system. A large number of estimators perceived that pressure was exerted for them to generate an estimate that was "reasonable and sellable". Some individual estimators felt that their superiors, as well as personnel at higher headquarters, were primarily interested in obtaining an optimistic (i.e., a low) estimate, one which was close to previous estimates made on the program and one which frequently reflected a need to achieve an optimal pattern of "luck" on all program activities (46; 47; 49; 50; 51; 52). Fox also supported this view. He commented that program managers frequently perceived that they had great difficulty transmitting reasonable estimates to higher headquarters. They reported that higher level managers tended to reduce the cost estimates to a low, more optimistic figure (10:160). This is not to say that any estimator or program manager falsifies any cost estimate. The estimator is merely internally motivated by the organization to provide an estimate which will help sell the program, one which assumes everything questionable will turn out well for the program.

3. Each organization involved in the study identified the lack of an adequate data base as a major problem faced by the individual estimator. The data in those data bases that do exist is not standardized from one program to another, nor is the methodology used to generate past

estimates included in the data base. As one estimator put it, "This makes the entire data base worthless, to say the least." This feeling that the data bases which are available are of little value prevailed in many of the organizations.

4. The authors encountered a major problem with the semantics involved in the techniques used by the estimators. Many estimators had different conceptions as to what the techniques actually were, or used different terminology for the same technique. The semantics problem occured in almost every organization involved in this research effort and was evident between the individual estimators within an organization. This confusion was also noted in the literature (reference pages 22 to 36).

5. The individual estimators are not held accountable for the accuracy of their estimates. In no organization visited could the authors establish the existance of a track record of an individual's estimates. In fact, the majority of the cost estimators were provided no feedback relative to their estimates on either an individual or a program basis. No feedback on the individual's estimates were formally made available to him. No data on estimates made by other individuals within his organization on the same program was provided to him. The estimates made by other organizations relative to the same program were not routed back to him. A few estimators in the SPOs took it

upon themselves to attempt tracking their own records, but this was the exception rather than the rule. In these few cases, it was individual initiative and not official organization policy to do so. Further, the estimator was not rewarded by the organization for this extra effort (47; 50; 52). An estimator in one organization reported that his organization did attempt to keep a track record of estimates. However, he indicated that the record was kept by program and did not identify the individual making the estimate. He further stated that the information kept was unofficial.

6. All cost estimators generally indicated that it was highly important to generate an accurate estimate. However, there was virtually no consensus from organization to organization (or from estimator to estimator for that matter) on how to define accuracy. The response to the question "What do you mean by accurate?" ranged from "Plus or minus 25% of final total cost." to "It varies from phase to phase." to "It's a relative thing." to "How close the estimate you make comes to the final cost for the system." Many interviewees could not/would not attempt to provide a definition of the term accurate--they responded instead with, "I don't know." When the measurement of accuracy was pursued, the question of whether or not it would be most appropriate to use actual dollar differences between the estimated and actual costs or to use percentage figures left

some estimators perplexed and uncertain. Many would prefer to provide a cost range rather than a point cost estimate. Almost without exception though, each estimator indicated that the estimates generated at his level of the estimating process provided the most accurate estimates (32; 37; 38; 39; 43; 44; 46; 47; 49; 50; 51; 52). Without a standardized definition of what "accuracy" means; it is difficult at best to determine if <u>any</u> of the estimates reflect actual program costs, let alone which estimate is most accurate.

One reason frequently given by many of the estimators for track records not being maintained by the organization are the continual changes that occur in each program. This reason was also put forth as the cause for not knowing how accurate the individuals cost estimates are. The estimators perceived this to be a major hindrance to providing accurate estimates for the program. Again, only a few estimators took the time to go back to their original estimates and update them to reflect the new information resulting from program changes.

The authors recognize that changes in program requirements and weapon system designs do occur, and that these changes do represent a major problem to the individual estimator. This is not, however a valid reason for the organization not attempting to keep individual track records, or not maintaining a data base which reflects the changes in past estimates resulting from these program changes.

Nor should these program changes confuse the issue of accuracy. There are, after all, many more stable aspects of a program than there are changes for the individual estimator. It may well be that the estimator should not be expected to be 100% accurate, particularly when program changes effect the items estimated. This does not, however, reduce the value of an accepted measure of accuracy and a formal system of feedback to provide accuracy data. Only by comparing the accuracy of one set of estimates to another can any real information be generated on what estimating techniques or models provide the most useful estimates for specific types of weapon systems in various weapon system program phases.

<u>Summary</u>. Within the AF cost estimating process, cost estimates are developed in an atmosphere of optimism. The cost estimator is provided organizational motivation to develop an estimate which can be used to advocate the new weapon system to the DOD and Congress. The individual estimator is hampered in his efforts to develop estimates by the lack of an adaquate, standardized data base; lack of feedback on the accuracy of his estimates; and little or no feedback on how changes have effected prior estimates. Further, while the estimators recognized the importance of "accurate" estimates, the authors could find no concensus as to what "accuracy" means.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this thesis was to investigate the cost estimation process within the Air Force. The study identified the organizations/agencies which make cost estimates and the points in time when they do so. The amount of data available for making cost estimates and the techniques employed to generate the estimates were also identified. The information collected in this investigation can be valuable in understanding the cost estimating process within the AF. It will also provide some insight into the quality and the limitations inherent in the Air Force's system for generating cost estimates on new major weapon system acquisitions.

The thesis was organized into a two phased effort:

1. to build a model of the cost estimating process for new major AF weapon systems from available literature sources, and

2. to demonstrate whether the model could be validated as realistically reflecting the real world estimating environment within the AF weapon system acquisition process. If not, to develop a model reflecting the actual AF estimating environment.

An extensive literature review was conducted to build the original model. Four phases of the weapon system acquisition process (the conceptual, validation, full scale development, and production phases) were identified as periods during which Air Force and Department of Defense organizations/agencies make cost estimates. Therefore, the weapon system acquisition cycle was used as the basic framework upon which the models were built. Approximately 80 individuals involved in cost estimating, from the SPO level through the DOD level, cooperated in extensive interviews during the validation effort.

Conclusions

A model of the Air Force cost estimating process for new weapon system acquisitions was constructed from the literature available. The model is presented in figure 3 (page 80). This model depicts what the concerned and industrious reader can interrupt from the available literature relative to the Air Force's cost estimating process for major weapon system acquisitions. The criteria established for this research effort, required that the real world estimating environment match the literature model 100% of the time for: (1) when an organization/agency would make an estimate; and (2) what techniques the organization/agency actually used. The literature-based model did not realistically reflect the real world estimating environment when tested against this criteria. The cost estimating techniques used by the SPO and ICA estimators in the validation and full scale development phases of the weapon system acquisition process did not support the model. The real world estimating environment, based on actual field interviews, is depicted in figure 4 (page 83). It is concluded, therefore that the available literature does not accurately reflect the "real world" of cost estimation for major AF weapon systems acquisitions.

It was found that the AF/DOD does not have an adequate definition of an "accurate" estimate. Further, the Air Force does not even recognize a standardized method of measuring accuracy. This deficiency has led to confusion among the individual cost estimators.

The feedback system for estimating accuracy within the AF is totally inadequate for the individual estimator's needs. Specifically, no structured feedback system exists. The limited amount of feedback available is not standardized or tailored to the individual estimator. If the estimator is to improve his estimating ability, he must be provided consistent, standardized reports. Preferably this will occur on an individualized basis and will indicate how well he has done in his previous estimating efforts.

The authors concluded that, in the majority of cases, the organizations/agencies involved in cost estimating for new major AF weapon systems act in a program advocacy role. It appears the ICA program as currently implemented does not produce a truely independent cost estimate as originally intended. AFSC, which conducts the majority of the ICAs, uses the Directorate of the Comptroller of the division (ASD, ESD, or SAMSO) to which the program is assigned to conduct its ICA. Thus, the same individual (division commander) is basically responsible for producing both the ICA and the SPO estimates. The authors perceive it as unlikely that under these circumstances, widely differing estimates could possibly be generated and forwarded for comparison.

The majority of cost estimates made within the AF cost estimating process are optimistic, and are apparently based on an optimal contractor and Air Force level of performance in the development, production and operation of the new weapon system. These estimates ostensibly result from the program advocacy roles assumed by the majority of AF/DOD personnel involved in weapon system acquisitions. It is apparent that over time, such optimistic cost estimates can cause the Congressional and Executive branches of the government to question the credibility of the Air Forces estimating system.

A final conclusion reached was that the estimators do not agree among themselves on the terminology to use in describing/naming the available estimating techniques, what they involve, and into which category a particular technique should be placed. In fact, agreement could not be found as to how many categories of techniques there really are.

In summary, the material gathered in this study leads the authors to believe that AF organizations from the SPO level up to and including the DOD do not create the conditions necessary to motivate estimators to develop estimates which truly reflect final total system costs for new major weapon systems. It should be emphasized that the authors are speaking of new weapon systems where little "hard-core" production data is available. The individual estimator is without an adequate data base from which to better the accuracy of his estimates: he is not provided feedback on the accuracy of his estimates, and how changes which have occurred effect prior program estimates; he is provided no feedback on how his individual estimates, which are part of the total estimate forwarded to higher level agencies compare with previous program estimates--his own, those made by others within his organization, or those made by estimators from outside his organization; and he is not provided with data on what the program final costs were or how his estimate compared with them (normally by the time the final costs for a program are available, the individual estimator is no longer associated with the program). The individual estimator is internally motivated to provide an optimistic estimate which can be used to advocate the weapon system to Congress.

Finally, while the estimators indicated they felt it was critical that the estimate be "accurate", there is no consensus as to what "accuracy" means. A rehetorical question might be appropriate at this point. "What motivates the individual estimator to generate an accurate estimate if he doesn't know what an accurate estimate is?" Further, "How can an estimator be expected to improve his estimates over time when he receives no feedback to indicate the type or amount of error which exists in his earlier estimates?" The results of this analysis thus led an unbiased observer to question, "What should be the AF's standardized and measurable definition of accuracy?"

Recommendations

A publication that shows the actual relationships between the organizations/agencies involved in the cost estimating process is required. This publication could be used to indoctrinate new individuals entering the cost estimating field. It could also be used to orient individuals currently functioning in the cost estimating field on how all facets of the system impart the final estimate generated on a weapon system. Such a publication would depict where the specific organization/agency fits into the overall AF cost estimating process. This thesis could be used as a basis for the publication. If the 14 organizations/agencies interviewed in this study, which are involved in making cost estimates for new weapon acquisitions, 12 requested copies of the final thesis. They expressed a hope that the thesis would provide an insight into the cost estimating process which could benefit their estimators. Unfortunately, this thesis will not carry the weight of an official AF document. Further, the organization of a thesis is not appropriate for providing the information in an efficient package for use by these organizations. A logical extension of this thesis would result in an approved compendium of cost estimating techniques which could establish a standardized AF terminology. This compendium, when developed, should be included in any publication developed to depict the AF cost estimating process.

The AF needs to establish a feedback system which identifies the individual generating the estimate, the phase of the weapon system acquisition cycle during which the estimate was generated, and the techniques/methodology used in generating the estimate, all in a standardized and comparable format across weapon systems. Developing and implementing this feedback system would facilitate the development of a standardized data base for use by all estimators when working on the cost estimates of future weapon system acquisitions.

The AF/DOD should begin to manage the cost estimating process as an entity in itself with the objective of improving cost estimating accuracy. To do this, four actions as a minimum are required:

1. Establish a consistent measure of accuracy based

upon a standardized definition of the term.

2. Develop and implement a feedback system based on the individual estimator and organizational program estimates.

3. Free the estimator from his perception of a need to produce optimistic estimates based upon an optimal performance in all facets of the program.

4. Develop and implement a positive/negative reward system based upon obtaining accurate estimates.

Recommendations for Future Studies

Based upon the absence of any concensus about the terminology of cost estimating techniques in the literature reviewed, and backed by the same finding among the individual estimators interviewed, the authors strongly recommend that future research be conducted to develop a compendium of the techniques used in cost estimating. The study should identify the techniques, explain how the techniques are used, and standardize the terminology relevant to each particular technique. Hopefully, the rationale for a categorization of the techniques could be developed with assistance from all levels within the AF cost estimating process for inclusion in the compendium. This compendium, when completed, should be included in the AF document recommended earlier.

Based upon the conclusion that the ICA program may not be functioning as originally intended, further research into the independence and use of the ICA estimate appears warranted. One of the possibilities to be investigated would be whether the ICA should be conducted by an agency completely divorced from the MAJCOM which produces the SPO estimate or perhaps by an organization totally independent from DOD!

Further research should be conducted to determine the design and content requirements for a standardized data base. The currect data basis should be analyzed to determine their shortcomings as well as their beneficial features. The research should involve the individual estimators to ascertain their requirements/desires relative to the information needed.

A final area which requires further research is the motivation of the individual estimator. Extensive research should be accomplished to identify the factors which motivate the estimator to generate good estimates. The pros and cons of a reward system based upon the measured accuracy of the individual estimator and/or his organization should be included.

The cost estimating process within the AF is typified by confusion and uncertainty in what is involved and how it works. This confusion and uncertainty is found among the estimators, those who act upon the estimate made, and at the Air Staff/DOD level. Additional research is necessary to further explain the process and thereby reduce the confusion and uncertainty. Air Force publications are needed to orient both new and experienced estimators to the realities of the Air Force estimating process. A better understanding of the cost estimating process is necessary if the AF/DOD is to reduce "apparent" cost growth and regain public and Congressional confidence in their ability to estimate accurately the costs of new weapon systems.

APPENDIX A

MANAGERIAL INTERVIEW SCHEDULE

MANAGERIAL INTERVIEW SCHEDULE

Type Interview________

Tape Number___________

Date__________________

I. General:

A. Personal and Organizational Data:

1. Name?

2. Organization/Division?

3. Job Title?

4. Length of time in current position?

5. Length of time as a cost estimator?

B. Purpose of Study: To clarify and document the overall cost estimating process used by the Air Force in the acquisition of major new weapon systems.

C. Purpose of Interview: To obtain your help in understanding what organizations/agencies provide cost estimates, the purpose for which the cost estimates are made, when in the acquisition process these cost estimates are generated, and what techniques are appropriate to each organization/agency in producing a cost estimate.

II. Specifics:

A. When are cost estimates generated?

1. During which phase of the weapon system acquisition process does your organization make cost estimates?

   a. Conceptual? __________

   b. Validation? __________

   c. Full-Scale Development? __________

   d. Production? __________

2. Can you differentiate between the phases when you make a cost estimate?

3. How do you differentiate?

4. Do you make more than one cost estimate during any one phase?

   a. Which phase?

   b. How many estimates are made?

   c. Why do you make more than one estimate?

   d. How are they different one from another?

B. Amount of Data Available.

1. How much data is available for making cost estimates in each of the following phases?

   a. Conceptual?

   b. Validation?

   c. Full-Scale Development?

   d. Production?

2. What type data do you use to make cost estimates in each of the following phases?

   a. Conceptual?

b. Validation?

c. Full-Scale Development?

d. Production?

3. What data would be required to make cost estimating easier?

    a. Why would this data be required?

    b. How would this additional data help?

C. Techniques used to make cost estimates.

1. What techniques are available to you to make cost estimates?

2. What techniques do you use to make cost estimates in each of the following phases?

    a. Conceptual?

    b. Validation?

    c. Full-Scale Development?

    d. Production?

3. Do you feel that the technique(s) currently used in each phase is the most useful one available?

    a. Why/why not?

    b. What techniques would be more useful?

    c. Why do you feel the techniques you suggested would be more useful?

4. Do you feel that the techniques currently used in each phase provides the best estimate possible?

    a. Why/why not?

b. What techniques would provide a more accurate estimate?

c. Why do you feel that the technique suggested would be better than the one currently used?

d. How accurate are your estimates?

e. Can you tell how accurate your estimates are?

f. How can you tell?

5. Do outside organizations/agencies attempt to influence you in the choice of the technique to use?

a. Who?

b. When?

c. Why?

D. Why are cost estimates made?

1. Why do you make cost estimates in each of the four phases?

a. Conceptual?

b. Validation?

c. Full-Scale Development?

d. Production?

2. Who uses the cost estimate made by you in each of the four phases?

a. Conceptual?

b. Validation?

c. Full-Scale Development?

d. Production?

3. What are the cost estimates used for?

a. Conceptual:

(1). Planning? __________

(2). Controlling? __________

(3). Other? __________

b. Validation:

(1). Planning? __________

(2). Controlling? __________

(3). Other? __________

c. Full-Scale Development:

(1). Planning? __________

(2). Controlling? __________

(3). Other? __________

d. Production:

(1). Planning? __________

(2). Controlling? __________

(3). Other? __________

E. Importance.

1. How important do you feel it is that the cost estimate you generate be accurate?

2. What do you mean by accurate?

3. How do your estimates compare with those made in other organizations?

4. Do outside organizations/agencies attempt to influence the outcome of your estimate?

a. Who?

b. When?

c. Why?

APPENDIX B

ORGANIZATIONAL LISTING OF INTERVIEWEES

ORGANIZATIONAL LISTING OF INTERVIEWEES

The following individuals, from the organizations listed, were interviewed in the process of validating the model developed in Chapter II and updated in Chapter IV.

AF CAIG (HQ AF/ACMC)

1. Fitzgerald, Major Dan (28 & 29 March 77)
2. Krushinski, Joseph (28 & 29 March 77)
3. Puryear, Captain Franklin G. (28 March & 19 April 77)

AFLC Comptroller (HQ AFLC/ACRC)

1. Jones, Captain Charlie E. (9 February 77)
2. Waker, Michael P. (3 February 77)
3. Wallace, John M. (4 February 77)

AFLC Plans (HQ AFLC)

1. Telford, Lt Col William D. (XRXXS) (23 March & 28 April 77)
2. Dellinger, Edward K. (MMA) (28 April 77)

AFLC ALC

1. Williams, William D. (WR-ALC/MMH(2)) (29 April 77)
2. Davis, Larry (OC-ALC/MMHA) (6 & 10 May 77)
3. Poe, Lt Col Joseph (OC-ALC/MMHA) (6 May 77)

AFSC Comptroller (HQ AFSC/ACCE)

1. Scarlett, Lt Col Bobby R. (28 & 29 March 77)
2. Sims, Captain Sherry (28 & 29 March 77)
3. Rasberry, Dayle H. (29 March & 10 May 77)

AFSC Plans (HQ AFSC/XRX)

1. Blake, Lt Col Thomas (4 February & 29 March 77)
2. Bando, Edward (19 May 77)
3. Sink, Captain John (19 May 77)

AFSC ASD Comptroller (ASD/ACC)

1. Adams, Charles W. (ACC) (10 January 77)
2. Richey, Lawrence S. (ACCC) (24 January 77)
3. Sampson, Charles E. (ACCC) (8 February 77)
4. Thorpe, Thomas E. (ACCC)(24 January 77)

AFSC ASD System Program Offices

ACCX-Advanced Systems Cost Division

1. Burnett, Robert V. (31 January 77)
2. Fetter, Donn P. (11 February 77)
3. Schlosser, Kelsey P. (11 February)
4. Weiler, Henry F. (2 February 77)

SD-28P-Airlift Systems

1. Ambrose, John R. (18 January 77)
2. Osborn, Donald A. (3 February 77)
3. Wethington, Clyde M. (27 January 77)

SD-65-Maveric Program

1. Schwenke, Captain Robert B. (31 January 77)

YFPR-F15

1. Conley, Robert (8 March 77)
2. Kouri, Donna (19 March 77)

YHPF-B1

1. Clapper, Captain William (10 February 77)
2. Townsley, ustin L. (16 February 77)
3. Frye, Thomas L. (16 February 77)

YMPM-Air Launched Cruise Missile Program

1. Allen, John A. (31 January 77)
2. Malhotra, Pran L. (21 January 77)
3. Wagner, Joseph T. (21 January 77)

YPKF-F16

1. Jack, Major James (3 February 77)
2. Thompson, Rick (24 March 77)
3. Ambrose, John J. (24 March 77)
4. Thorp, Thomas E. (24 March 77)

YXPC-A10

1. Murchand, Richard C. (2 February 77)
2. Bigood, Leroy (2 February)

AFSC ESD Comptroller (ESD/ACCE)

1. Coakly, Ellen M. (22 February 77)
2. McNeil, Hugh W. (24 February 77)
3. Wisialko, Albert J. (23 February 77)

AFSC ESD System Program Offices

YSXF-Airborne Command Post

1. Seigel, Robert (25 March 77)
2. Melanson, Robert (25 March 77)

YWXF-Airborne Warning and Control System

1. Patrick, Major James (18 March 77)
2. Grones, Captain Royce (11 March 77)
3. Roberts, Captain Kenneth M. (11 March 77)

AFSC SAMSO Comptroller (ACCE)

1. Cook, George M. (18 February 77)
2. Green, J. Richard (19 January 77)
3. Tomlinson, Robert L. (18 February 77)
4. Townsend, Lt Richard L. (17 February 77 & 24 March 77)

AFSC SAMSO System Program Offices

ACCE-Comptroller (in support of SPOs)

1. Fong, Franklin K. (24 March 77)
2. Martin, Martha A. (17 February 77)
3. Wilcox, Leonard (24 February 77)

LV-Launch Vehicles

1. Kelley, Lt Col Gilbert F. (3 March 77)
2. Kisko, Captain William A. (7 March 77)
3. Pearse, Major James P. (10 February 77)

MNPC-ICBM Program Office

1. Wall, William E. (4 March 77)

SKP-Space Communications

1. McCoy, Lt Col Donald G. (18 February 77)

YDC-Defense Meteorological Support Program

1. Clovicko, Lt Cary (11 February 77)

YRP-Satellite Data Systems

1. Figueroa, Captain Francisco A. (10 February 77)

HQ Aerospace Defense Command (ADCOM)

1. Behrends, James L. (ADCOM/ACBA) (1 February 77)
2. Smith, Major Bruce E. (ADCOM/XPX) (1 February 77)
3. Whitaker, Captain Richard B. (ADCOM/XPDS) (8 February 77)

HQ Military Airlift Command (MAC)

1. Nelson, Captain Eric E. (MAC/LGXP) (3 January 77)
2. Stauffer, Captain Christian W. (MAC/ACMC) (10 February 77)

HQ Strategic Air Command (SAC)

1. Ellinger, Captain Robert W. (SAC/XPQR) (4 February 77)
2. Wade, Major Tommy H. SAC/ACMC) (4 February 77)

HQ Tactical Air Command (TAC)

1. Buttross, Captain David A. (TAC/ACMC) (14 February 77)
2. Whelan, Major Charles (TAC/DRDR) (9 February 77)

OSD CAIG (OSD (P&E))

1. Pilling, Lt Cmdr Donald (28 & 29 March 77)
2. Manetti, Howard J. (29 March 77)

APPENDIX C

GLOSSARY OF TERMS

GLOSSARY OF TERMS

<u>Advocacy Package</u>: The documents necessary to present the conclusion of the Conceptual Phase study and the various conceptual alternatives, along with the studies and tests of these alternatives. The package recommends one particular alternative concept. The advocacy package is used to "sell" the program to OSD.

<u>Budget Cost Information</u>: Information on proposed alternative solutions, costs, and schedules for satisfying a ROC. Normally prepared by AFSC and/or AFLC in response to a published ROC.

<u>Budget Costs</u>: Costing used in budget submissions as distinguished from costing used in program documents. Budget costs represent the specified total obligation authority requirements for funds in a particular fiscal period and generally represent a refinement of program costs.

<u>Configuration Item</u>: An aggregation of hardware/software, or any of its discrete portions, which satisfies an end use function and is designated by the Government for configuration management. During development and initial production, CI's are only those specification items that are referenced directly in a contract (or an equivolent in-house agreement).

<u>Cost Analysis Improvement Group (CAIG)</u>: An OSD (AF) advisory body, responsive to the DSARC (AFSARC) on matters relating to

cost. The CAIG provides the DSARC (AFSARC) with a review and evaluation of independent (ICA) and program (SPO) cost estimates prepared by the Military Services. Established to develop uniform criteria to be used by all DOD units making cost estimates.

Cost Category: One of three types of costs into which the total cost of a program element is divided (1) research and development, (2) investment, and (3) operations.

Cost Estimate: The product of an estimating procedure which specifies the espected dollar cost to perform a stipulated task or to acquire an item. It may be stated as a single value or range of values.

Cost Estimating Relationship (CER): An analytical expression which describes, for predictive purposes, the quanity or cost of an item or activity (either in physical units or dollars) as a function of one or more explanatory variables.

Defense System Acquisition Review Council (DSARC): An advisory body, within the Office, Secretary of Defense, which is chartered to review and evaluate the status of each appropriate system acquisition program at three basic milestone points. Membership is composed of The Director, Defense Research & Engineering (DDR&E), the Assistant Secretary of Defense (Comptroller (ASD Comptroller)), the Assistant Secretary of Defense (Installations and Logistics (ASD (I&L)) and the Assistant Secretary of Defense (Systems Analysis) (ASD (SA)). The three milestone points in the weapon system acquisition process which require DSARC review and evaluation are:

1. When initiation of Contract Definition (or equivalent effort) is proposed;

2. When transition from the Contract Definition Phase to full scale development; and

3. When transition from the development phase into production for Service deployment is proposed.

Development Concept Paper (DCP): Memoranda from the Secretary of Defense expressing his decisions on the initiation of, or changes to, major R&D programs.

Five Year Defense Plan (FYDP): The official program which summarizes the Secretary of Defense approved plans and programs for the DOD.

Independent Cost Estimate (ICE): An estimate of program cost developed outside normal advocacy channels by a team which generally includes representation from Cost Analysis, Procurement, Production Management, Engineering and Program Management. Synonomous with Independent Cost Analysis (ICA) in this paper. An ICA generally involves maximum use of parametric techniques but may use other cost estimating techniques.

Industrial (Detailed) Engineering Estimate: A cost estimate based on manufacturing, assembly, and test costs generated from system description operations, or standards designed from time and motion studies or vender quotes. Also known as industrial buildup or grass roots estimates.

Official Program Estimate: The estimate prepared by a System Program Office of Aeronautical Systems Division, Electronics System Division or Space and Missile System Division.

Parametric Cost Estimate: A cost estimate which is based on the development and utilization of estimating relationships between historical costs and other program variables such as system physical/performance characteristics, contractor output measures, manpower loading, and facility floor space.

Planning/Programming/Budgeting System (PPBS): An integrated system for the establishment, maintenance, and revision of the FYDP and the DOD budget.

Program Management Directive (PMD): A USAF document which transmits to AFSC the "go-ahead" and guidance for the new weapon system following the DSARC I decision.

Required Operational Capability (ROC): A formal, numbered document, used to identify an operational need and to request a new or improved capability for the operating forces. The capability sought is described in terms of operational objective, operational environment, support and maintenance concepts, and concept of operation.

System Program Office: An AFSC management organization set up to manage the acquisition of a new weapon system.

Total System Cost: Total system cost encompasses costs for development, procurement, operation, and support, and where applicable, disposal. Total system cost is analogous with life cycle cost.

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