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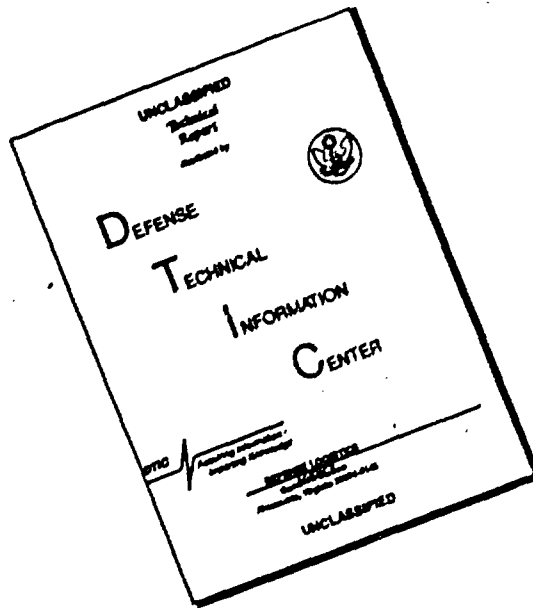
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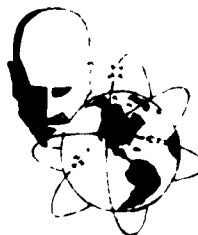
**BIDDER COST ESTIMATES AS A DATA BASE  
SOURCE FOR ADVANCED SYSTEMS COSTING**

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-63-251

July 1963

M. V. Jones

Prepared for  
PROGRAMS DIVISION, COMPTROLLER  
ELECTRONIC SYSTEMS DIVISION  
AIR FORCE SYSTEMS COMMAND  
UNITED STATES AIR FORCE  
L. G. Hanscom Field, Bedford, Massachusetts



Prepared by

THE MITRE CORPORATION  
Bedford, Massachusetts  
Contract AF19(623)-2390 Project 550

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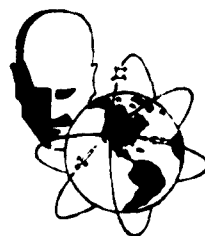
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**THE MITRE CORPORATION  
Bedford, Massachusetts  
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#### ABSTRACT

This paper proposes that bidder cost estimates received in the course of a system source selection be included in the data base for costing advanced military systems. The paper discusses the advantages of bidder cost estimates as a data base source, suggests some precautions that should be observed in using these estimates, recommends standards necessary for their most effective utilization, and identifies the types of cost estimating data that might be derived from bidder cost estimates.

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## 1.0 INTRODUCTION

Advanced systems costing, like other forms of economic forecasting, draws upon two basic types of data inputs. First, there is recorded historical experience, both military and industrial, covering costs of either systems analogous to the future system being costed or subsystems or elements similar to those in the future systems. Second, in one way or another the analyst needs to supplement historical data with projections and informed opinions that will reflect as fully as possible the manner in which the future system and its elements will differ from current systems on which historical data have been accumulated. This latter type of data is necessary for two reasons. First, there are often too few historical observations to serve as a satisfactory base from which to estimate future costs. Second, historical cost data frequently have limited relevance in estimating future costs because future systems and the types and quantities of resources required for future systems will differ significantly from current systems and their resource requirements.

In recent years the Air Force has taken an important step toward increasing its capability to cost advanced systems by establishing a standardized contractor cost reporting system. On the one hand, this system formalizes one of the most important aspects of the historical data base by requiring contractors for diverse military systems to report their cost experiences on a comparable, relatively consistent format. Since a good knowledge of the costs of current systems facilitates the costing of advanced systems, the contractor reporting system will become increasingly useful for advanced systems costing as a larger body of historical data is accumulated in succeeding years. In addition, this reporting system provides an important source of informed opinion in that it requires contractors to project and update periodically their estimates of the costs to complete the systems.

This paper proposes generally that greater provision be made for incorporating informed opinions into the data base for costing advanced systems. Specifically this paper examines the potentialities of bidder cost estimates generated in the course of a system source selection as one useful source of informed opinion. The remainder of the paper will discuss the basis of this proposal, some precautions applicable to its adoption, the conditions necessary to achieve its maximum effectiveness, and the types of useful data that might be derived from bid proposals.

## 2.0 ADVANTAGES OF BIDDER COST ESTIMATES

One advantage in using bidder cost estimates is that they are, for the most part, generally available. No new reporting requirements would have to be imposed on industry since the bidder estimates are already a standard requirement for all system source selections. Since some processing of these costs is accomplished during the source selection, a relatively modest analytical and clerical workload would be required to convert the raw cost data to a form from which generalizations could be made that would be useful in costing other systems in the future.

A second advantage of bidder cost estimates is that they provide one of the earliest means in the life of a system of obtaining comprehensive, formal, expert opinion relative to the system's probable cost. Since there is normally a general scarcity of pertinent historical cost data during the early stage of an advanced system's development, it is important to extract whatever insight might be provided from an analysis of the bid costs. Although the contractor cost reporting system will subsequently provide interim reports on actual contractor costs as the system develops, it generally will be a number of years before complete life-cycle historical reports of a system's costs become available.

One of the most important advantages that bidder cost estimates offer is the opportunity they provide for multiple "observations" relative to a system's costs. This means of increasing the size of the sample from which cost estimating relationships can be developed can hardly be over-emphasized. One of the most serious problems that system cost analysts have faced is the requirement that they work with extremely small statistical samples. Often this has meant that a cost analyst must derive his estimate of the cost of an important element of a future system largely on the basis of the costs of a single, somewhat similar cost experience -- current or past. In order to increase the sample size, it is often necessary to use data pertaining to systems differing significantly in mission, configuration, and time phasing. With such small samples of data drawn from a heterogenous base, projections of the costs of a future system are of doubtful validity. On the other hand, source selections may provide a dozen or more cost estimates made during the same time period for the same system requirement. The multiple estimates thus make it possible to draw upon the cost experiences of many competent authorities and, hence, reach some consensus of expert opinion. Under such circumstances it is easier to identify an atypical estimate, to evaluate it, and, if appropriate, to discard it. Finally, the multiple estimates make it possible to manipulate the cost data statistically, such as expressing quantitatively some of the uncertainties involved. For instance, ranges and probability distributions, which can be useful in advanced systems costing, could possibly be calculated.

Under appropriate circumstances<sup>1</sup> a system source selection provides a more reliable means of soliciting industry's cost opinions than other less formal means. Considerable time and effort go into the preparation of the list of companies invited to bid on a system acquisition contract so that it is unlikely that a highly competent source will be bypassed or a questionable source solicited for a cost estimate. The format requesting the cost data is formal, written, and standardized. The fact that the cost data must be formally presented in writing by the bidder is normally a motivation for relatively careful estimating. The further knowledge that the cost estimate will be painstakingly reviewed by a team of government cost analysts and evaluated not only for internal consistency but also for general plausibility against competing bidders also encourages

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<sup>1</sup>These circumstances will be discussed in section 4.0.

careful estimating. Bidders have a relatively strong motivation for spending substantial time and money in preparing their cost estimates, since the successful bidder will normally receive a multi-million dollar contract to perform the work he bids on and will generally be held responsible for carrying out the work he bids on within the general price range of his cost estimate.<sup>1</sup> The growing trend toward fixed price and fixed price-incentive contracts will increase the motivation for better estimates.

### 3.0 PRECAUTIONS IN USING BIDDER COST ESTIMATES

Bidder cost estimates, like most other sources of data for advanced systems costing, have certain shortcomings. Since promiscuous application is a potential problem relative to data obtained from any source, it is pertinent to identify the major precautions that must be heeded in using bidder costs.

First, there is the possibility of estimating bias. Bidder cost estimates are prepared as only one part of a proposal in which each bidder tries to sell the Air Force on his total capability to contribute to the fulfillment of a stated military requirement. Although certain characteristics and conditions of a source selection generally encourage careful and accurate estimation by the bidders, as indicated in section 2.0, the total procedure is highly competitive and a bidder is motivated to quote a low price in order to improve the chances of being considered for the contract award. The bidder may also be more concerned about the competitive level of his total price than about the accuracy of specific cost elements. These possibilities further highlight the desirability of securing and comparing cost estimates from multiple sources and for deriving a consensus of expert opinion relative to the cost of specific elements.

The subject of bias in cost estimates is both important and complex. However, as suggested in footnote 1 below, all increases in contract prices over bid prices cannot be taken as evidence of deliberate bias. The great uncertainties inherent in system costing make all cost estimates susceptible to substantial honest error and careful empirical studies have indicated that even the cost estimates of unbiased sources are subject to considerable error.<sup>2</sup> Finally, even though many source selections have suffered

<sup>1</sup>The fact that the successful bidder sometimes negotiates a substantially higher contract price than his bid price does not negate this statement. Real-world contract prices are complicated by the fact that military requirements are sometimes upgraded subsequent to the bid evaluation and the successful bidder is called upon to furnish a more expensive system than he submitted his proposal on.

<sup>2</sup>Numerous RAND studies by Alchian, Brussel, Marshall, Mechling, Wisely, and others have studied the nature, source and magnitude of error in cost estimates. One of the latest is Robert Summers' study, "Cost Estimates As Predictors of Actual Weapon Costs: A Study of Major Hardware Articles (U)," RM-3061, April 1962.

from bias in bidder cost estimates, it is reasonable to anticipate that increasing Air Force experience with the system source selection procedure will reduce both the opportunity and incentive for bias, especially if action continues to improve such procedure along the lines indicated in section 4.0 of this paper.

It is also important to realize that a system source selection generally provides multiple cost estimates of meeting an equivalent requirement, as defined by the system performance specifications. The source selection does not provide multiple cost estimates of an identical equipment configuration because the equipment configuration and other design details proposed by various bidders may differ substantially. Although it would be useful to have multiple estimates covering an identical design, this lack does not invalidate use of the data for most advanced systems costing. In other words, in such costing the analyst is normally working at a high level of aggregation and his objective is to estimate the costs of major subsystems or tasks (design, testing, integration, training, maintenance, etc.). Since the multiple bidder estimates can provide a useful consensus of expert opinion relative to the costs of major subsystems, tasks, or activities, the bidder costs can be a useful data input for advanced systems costing notwithstanding differences in the detail of the equipment configuration.

A notable shortcoming of bid proposal costs as a data input for advanced systems costing is the lack of supporting documentation detailing the derivation of the basic bid cost data. However, progress has been made in standardizing and carefully defining the categorization of data to be furnished by bidders and it may be expected that this progress will continue in the future.

Bidder costs cannot serve as a data source for all cost elements pertinent to total activity costing of a system because source selections provide estimates only of the contractor generated portion of total system costs. No estimates are provided of the portion of total system costs incurred directly by the Air Force, such as military and government civilian salaries, travel, training, etc. Also, the cost classifications used in source selections may not provide the data properly broken down for calculating all contractor type cost estimating relationships (CERs) required for advanced planning purposes.<sup>1</sup>

Although the purpose of this section has been to indicate that bidder cost estimates do not offer any quick and easy solution to the data base problem associated with advanced systems costing, it should be remembered that other sources of cost data also have limitations. Hence,

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<sup>1</sup>A comprehensive outline of the type of CERs required for an electronic system cost model is presented in MITRE TM-3364 (TDR 63-310, AD 290540) (Jannsen & Glazer) "Electronic System Cost Model."

it is important that an analyst use all the data sources at his disposal in developing cost estimating relationships, adjusting wherever he can for whatever deficiencies each of them may have.

#### 4.0 SUGGESTIONS FOR IMPROVING BIDDER COST ESTIMATES

The reliability and usefulness of bidder cost estimates for systems costing, as well as for bid evaluation, can be improved by further clarifying instructions to bidders in the following areas:

- 1 It is very important that bidders have a clear understanding of the requirement on which they are bidding. If the requirement is loosely defined, bidders will propose systems with substantially different capabilities and their cost estimates will be difficult to compare. Under such circumstances, the advantage of multiple cost estimates, cited in section 2.0, will be significantly reduced. In practice it has not been uncommon for the high bid to exceed the low bid by a factor of two or three primarily because the bidders were not proposing equivalent systems. To lessen this problem, the instructions to bidders should clearly translate the general statement of system requirements into specific performance specifications. The more pointedly this translation is accomplished, the more likely are bidders to propose equivalent systems, and the more useful are cost data extracted from these bids likely to be as a source of expert opinion for future costing studies.<sup>1</sup>
- 2 It is important that bidders be supplied with a standard set of cost elements, in terms of which total costs are to be subdivided, accompanied by clear, standard definitions of these cost elements. The discretion allowed the bidder in classifying costs should be minimized for two reasons. First, if bidders define and classify costs differently, there is likely to be little apparent correlation in the cost data they submit, even though they may expect to incur equivalent costs for similar elements, or if apparent correlation does appear it may be invalid and misleading. Second, unless a standard set of cost elements is used from one source selection to the next, the cost estimating relationships derived from any given source selection, however validly they may generalize on that particular source selection, will be difficult to apply to another future system having a different cost structure.

The Air Force has made good progress in standardizing cost estimating requirements. Contractors are required to report on

<sup>1</sup>The desirability of clarifying the system requirement for all bidders must not be confused with a standardization of the design details of the system. As much as possible, especially in the advanced planning stage of a system's life cycle, it is desirable that the scientific-engineering talent of industry contribute to the detailed design of the system. In other words, instructions to bidders should define the system performance specifications, but not the specific detailed design to meet those performance specifications.

a prescribed format, and recent source selections have included prescribed definitions for the elements in the prescribed cost format. Further progress in the future lies in implementing a standardized format among different source selections and in clarifying the definitions of some of the cost elements.

3. As much as possible the requirements for supporting detail to the cost estimates should be prescribed with the objective of requiring all contractors to invest equivalent time and care in preparing their data. If the cost submissions from various bidders are to be incorporated as an input into general estimating relationships, it is necessary either to determine that all submissions are of equal quality and, hence, can be given equal weight, or some method must be devised for discounting poorer quality estimates. At the present time the submissions from contractors vary considerably in both the type and detail of their documentation and, therefore, it is difficult to weight them properly in deriving general cost estimating relationships.

#### 5.0 APPLICATIONS OF BIDDER COST ESTIMATES

One of the barriers to the application of statistical techniques in advanced systems costing up to now, particularly in the command and control systems area, has been the great dearth of data, which could be subjected to analysis. As indicated previously, cost analysts have frequently been obliged to base their estimates of the costs of major elements of new systems on the cost experiences of one or two contractors working on one or two somewhat analogous current systems. On the other hand, the multiple cost estimates provided by source selection procedures should make it possible to use ranges, probability distributions, and other statistical techniques. Moreover, since the source selection procedures require bidders to submit their system costs in considerable detail and classified on several bases, it should be possible to extract several types of relationships and to use them for several purposes in costing a new system.

In the first instance, an accumulated body of bidder cost estimates, consolidated from numerous varied source selections could be used quickly to double check or corroborate a cost estimate of a new system independently derived from historical cost relationships or derived from direct research of military or industrial sources.

Second, an analysis of bidder cost estimates covering several or numerous source selections might be used directly to estimate certain costs of new systems simply because no better basis for estimating these costs was available. Illustrative of this application would be the costs of equipment, tasks, or elements involving advances in the state of the art for which no previous experience data existed.

The analysis of bid costs might find formal expression in at least two ways. On the one hand, a wide variety of percentage relationships might be calculated. For instance, percentage relationships between one

type of costs and another type of costs might be calculated, e.g., initial spares vs. equipment investment, equipment design vs. equipment investment, etc. When it is possible to estimate one type of cost directly, such percentage relationships could be used to estimate the other type of cost.

In addition, ratios could be calculated which would express the relationships between total contractor costs and some portion of total contractor costs. e.g. the display subsystem as a per cent of total contractor costs, data as of per cent of total contractor costs, testing costs as a per cent of total contractor costs, etc. This type of ratio could be useful, as indicated previously, to corroborate cost estimates derived from other sources. Such "percentage of total costs" type ratio could also be used to calculate directly certain hard-to-estimate costs, such as systems management, which frequently are calculated as residual or "percentage of effort" items.

Source selections might also provide a wide variety of "catalog" type costs which would reflect the consensus of expert industrial opinion relative to the anticipated dollar costs for accomplishing certain specified tasks or acquiring certain designated resources or assets. In this case, as in others, the care and detail used to define the task or describe the resource or asset would determine the usefulness of the cost relationship derived

Brief mention should be made of one administrative, political type obstacle to the use of bidder estimates for advanced planning purposes. Bidder data are highly sensitive and proprietary, and the Air Force has strict regulations governing the control and dissemination of this information to insure that the data are not used either to promote or undermine the competitive position of any company. Fortunately, there would be no need to violate the confidential status of bidder data in order to derive cost estimating relationships from these data and to use these relationships in advanced systems costing. The value of the bidder data lies in the general relationships that might be inferred from them; the particular estimate of any given contractor is largely immaterial.

There are many parallels to this situation in public life. For instance the Internal Revenue Service has a legal and moral obligation to withhold the data reported on an individual's or corporation's income tax return from public scrutiny or even from other government agencies unless "definite need to know" has been established. This requirement does not however prohibit the Internal Revenue Service from making many consolidations of the raw data appearing on individual tax returns, from manipulating the consolidations in many ways, and from publicizing the consolidated and evaluated results. This type of activity does not compromise the sanctity of the individual tax return. Similarly, the benefits of preserving some of the generalized statistics of a source selection could be obtained without compromising the valid objectives of keeping the raw bidder cost estimates proprietary.

## 6.0 SUMMARY

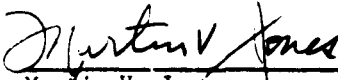
The system cost analyst must take an eclectic approach toward his sources of cost data. Among other things this means that he must broaden his concept of a cost data base to include more than historical data. He must supplement the historical portion of his base data with expert opinions pertinent to the future costs he is trying to estimate.

He must do this for two reasons. In the first place, large-scale, automated command and control systems are a recent development and only a relatively small historical data base on such systems has been accumulated to date. For certain types of costs, an historical data base is practically non-existent. Second, rapid advancements in technology are making the configurations of new systems dramatically different from current systems and, in the process, will invalidate many of the cost estimating relationships derived from the limited historical data that are available.

In seeking to augment his total supply of useful cost data, both historical and projected, the cost analyst should seek first to utilize as fully as he can data already compiled for other purposes. As indicated previously, the cost projections periodically made by contractors in the contractor cost reports could be very useful in estimating the costs of advanced systems. Second, a relatively large number of independent cost estimates of many, varied advanced systems are being made by both government and private organizations. Some means must be found for systematically tapping this fund of data to extract generally applicable cost estimating relationships.<sup>1</sup> Third, as proposed in this paper, cost estimates furnished by industry in the course of system source selections offer a fertile, relatively untapped source of expert industrial opinion on future system costs.

Finally, in drafting methods to retrieve both historical and projected cost data, the analyst should aim toward the widest possible application of the relatively small body of available data. There is, for example, no reason why in costing a new system such as BUIC (Back-Up Interceptor Control), it should not be possible to benefit to some extent from the cost experiences derived not only from a similar system, such as SAGE (Semi-Automatic Ground Environment System), but also from other command and control systems, such as BMEWS (Ballistic Missile Early Warning System), SACCS (Strategic Air Command Control System), and even weapon systems, such as Atlas, Titan, Polaris, and Nike Hercules. To accomplish such broad application, it will be necessary to devise workable methods for systematically modifying general purpose CERs to fit the particular application contemplated. A later paper in the present cost methodology series will make an initial approach toward establishing such a method.

<sup>1</sup>Within the Air Force, AFSC has taken initial action toward such consolidation.

  
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